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The Resources Agency

Department of Water Resources

BULLETIN No. 193

DESALTING ALTERNATIVES IN TEN CALIFORNIA COMMUNITIES

Reconnaissance Evaluation Report

DECEMBER 1974

NORMAN B. LIVERMORE, JR.
Secretary for Resources
The Resources Agency

RONALD REAGAN
Governor
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FOREWORD

This bulletin contains a reconnaissance-level assessment of desalting techniques that might be used to provide good quality water supplies in ten small and medium-size isolated California communities. In all but one of these communities, excess salts in local ground water have created a problem. This bulletin describes how each community might use desalting to either augment or improve its water supply.

The wide disparity in distribution of California's surface water has resulted in water deficiencies in some parts of the State. In general, the greatest quantities of surface water are in the north coastal area and the Sacramento Basin. In Central and Southern California, a large number of small- and medium-size isolated communities must depend on poor-quality ground water for their water supplies. In some cases, public health is an issue.

With today's knowledge and interest in public health, most citizens have become aware of the importance of good-quality water. Moreover, many citizens are beginning to demand that their water be of low salt content and free of (1) toxic and corrosive substances, (2) harmful organic and biological matter, and (3) objectionable taste and odor.

Most physical and bacteriological constituents can be removed by filtration and coagulation. However, with the exception of the hardness ions, i. e., bicarbonates and some phosphates, such treatment processes will not remove dissolved salts. On the other hand, the capabilities of today's desalting processes range from the removal of particular ions to the removal of essentially all dissolved substances.

For each of the communities, the water supply problem is described, several desalting systems are evaluated and their costs are determined, and the benefits are discussed. In three areas, the desalting of water from San Francisco Bay or sea water was assessed as a supplemental water supply. Costs are relatively high but may be justified as a domestic water supply.

The Department of Water Resources acknowledges the technical assistance and partial funding provided by the U. S. Department of the Interior, and the information provided by representatives of the communities studied and by various manufacturers of desalting equipment.

John R. Teerink

John R. Teerink, Director
Department of Water Resources
The Resources Agency
State of California

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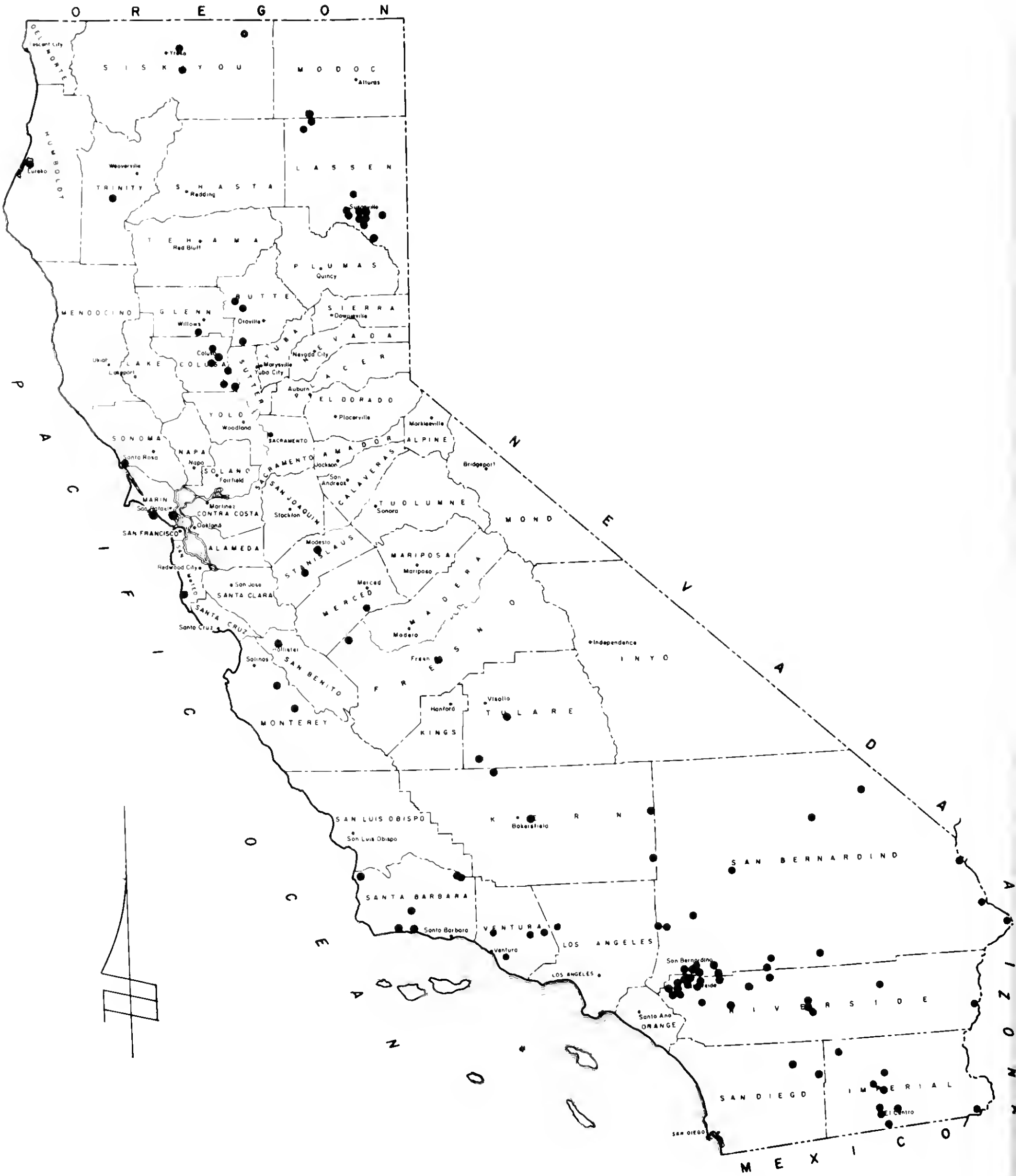


Figure 1. Location of California Communities in Inventory

I. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In many small- and medium-size California communities, most of which use ground water, salts in municipal water supplies have created water quality problems. A recent inventory by the California Department of Water Resources revealed 111 communities (Figure 1) where local water supplies were brackish and in some cases of marginal quality for beneficial use. Data from the inventory were set forth in a report titled"Inventory of Small- and Medium-Size California Communities with Brackish Water Supplies".[1]

The Department of Water Resources and the Office of Saline Water[2] of the U. S. Department of Interior determined jointly that 10 communities could be studied effectively, and that the communities selected represent typical conditions that generally apply to most if not all of the isolated communities included in the inventory. The most significant criteria used in the selection were the degree of need for improvement in quality of water, community interest in making the improvement, and the demand for improvement by regulatory agencies.

This bulletin, "Desalting Alternatives in Ten California Communities", reports the results of a reconnaissance-level, or preliminary, assessment of the ten selected California communities (Figure 2) where desalting might be used to improve water supplies or to provide a supplemental sources of water within the next five years. Most of the communities selected are located in Southern California. All but one are rural communities, with the exception being the Marin Municipal Water District, which serves several urban areas adjacent to San Francisco Bay. All 10 were selected on the basis of the need for, and/or community interest in, water supply improvement except for the Marin Municipal District where the interest is in the evaluation of desalting of San Francisco Bay water as one alternative to providing an additional water supply.

The 10 communities are:

1. Boron, a desert residential community;
2. Buellton, a coastal valley residential community;
3. Greenfield, a coastal valley agricultural center;
4. Old Cuyama, an interior valley agricultural community;
5. New Cuyama, an interior valley residential community;
6. Havasu, a desert community for retired persons and for weekend use;
7. Winterhaven, a desert residential community;
8. Marin Municipal Water District, a water district serving several urban communities near San Francisco Bay;
9. Refugio State Beach; and
10. Gaviota State Park, both of which are State operated recreation areas on the Pacific Coast.

In each community, local water supplies were evaluated, the most practical desalting processes were determined, and cost of required facilities were estimated. Data provided by the Office of the Saline Water and vendors of desalting equipment were used as the basis for cost estimates of facilities required for pretreatment of feed water, desalting, posttreatment of product water, blending, and disposal of brines.

The evaluation of each community (in Chapter 4) describes (1) the community in general, (2) the water supply, (3) the salt problem, (4) possible desalting applications, and (5) estimated benefits. For each community, estimated cost in dollars per 1,000 gallons were determined for each desalting process considered practical. The wide range in unit costs is due to the differences between communities in (1) salinity of water to be desalted, (2) quantity of water to be desalted, and (3) desalting-unit load factor, which is the proportion of the annual design capacity that would actually be produced by the desalter.

The following is a brief summary of the evaluation of each of the 10 communities:

Boron. Local brackish ground water is delivered to about 700 connections. The estimated annual water requirement is about 165 million gallons. The concentration of total dissolved solids in this water is about 1,030 ppm. There is a need to improve the quality of the water supply, which contains high concentrations of both total dissolved solids (TDS) and chlorides that exceed the recommended limits set by the California Department of Health (see Appendix D). Hardness has also created problems.

The lowest cost desalting process that would improve the quality is reverse osmosis at an estimated cost of $0.70 per 1,000 gallons of product water. The principal alternative water supply is state project water delivered under contract with the State of California to the Antelope Valley—East Kern Water Agency. In June 1974, a favorable vote on a bond issue appears to have ensured Boron that high quality state project water will soon be available.

Buellton. The Buellton Community Services District delivers brackish ground water to about 400 con-

[1] Available in DWR Files.

[2] Since July 30, 1974, a part of the Office of Water Research and Technology

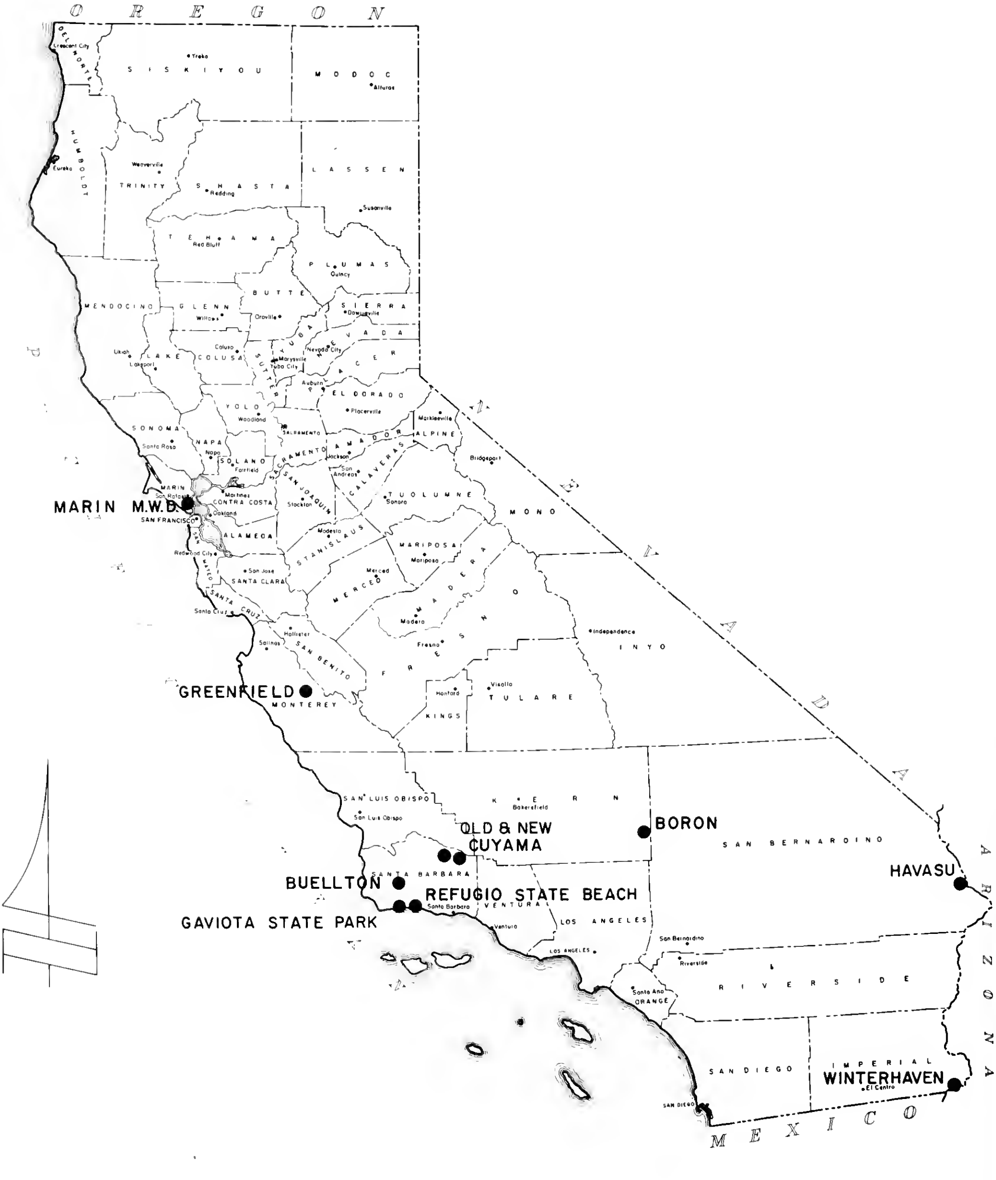


Figure 2. Communities Selected for Study

nections. The estimated annual water requirement is about 110 million gallons. The concentration of total dissolved solids in this water is about 790 ppm and the hardness is about 560 ppm. The need to improve the water supply is due to both hardness and high concentrations of total dissolved solids, as well as manganese and iron. The use of water softeners to reduce the hardness has created a waste water disposal problem, because the salt added to regenerate the water softeners increases the salinity of the waste water. The California Regional Water Quality Control Board, Central Coast Region, has set new limits on this disposal as a means to remedy the problem.

The lowest cost desalting processes that would improve the water supply and correct the disposal problem are either ion exchange or reverse osmosis at an estimated cost of about $0.95 per 1,000 gallons for each process. It appears that a lime-soda softening treatment proposed by the consulting engineer for the District would soften the water supply to desired levels for a lower unit cost; however, the disposal of wastes from this treatment process will be more of a problem than with the reverse osmosis process. It appears that a lime-soda softening treatment proposed by the consulting engineer for the District would soften the water supply to desired levels for a lower unit cost; however, the disposal of wastes from this treatment process will be more of a problem than with the reverse osmosis process.

Greenfield. Local brackish ground water is delivered to about 550 connections. The estimated annual water requirement is about 110 million gallons. The concentration of total dissolved solids in this water is about 720 ppm, and the hardness is about 490 ppm. There is a need to improve the water supply due to both hardness and high concentrations of total dissolved solids. The TDS exceeds the recommended limit set by the Department of Health; however, hardness is the greater problem. Water softeners used to reduce the high hardness appear to have indirectly caused waste water disposal problems. The California Regional Water Quality Control Board, Central Coast Region, has set new limits on waste water disposal as a means to remedy the problem.

The lowest cost desalting process that would improve the water supply is ion exchange at an estimated cost of about $0.75 per 1,000 gallons. Since hardness is the principal problem, the lime-soda softening processs may be desirable as in Buellton; however, the present water source for the community is a well located in a developed urban area where sufficient land required for installation of the lime-soda process may not be available.

Old Cuyama. Local brackish ground water is served to about 50 persons in this small community. The estimated annual water requirement is about 4 million gallons. The concentration of total dissolved solids in this water is about 4,300 ppm, and the hardness is about 2,600 ppm. The principal water supply conditions that create problems are the very high concentrations of total dissolved solids, sulfates, and nitrates and a very high hardness. Efforts to rejuvenate and futher develop this community have been blocked by the California Department of Health requirement that the water supply must be improved first.

The lowest cost desalting process is reverse osmosis at an estimated cost of $4.45 per 1,000 gallons. This unusually high cost is due to high salinity, small quantity of desalted water, and a low load factor. It appears that a more feasible alternative will be to import a water supply from one of the other ground water sources in the Cuyama Valley, such as New Cuyama.

New Cuyama. Local brackish ground water is delivered to about 200 homes and commercial and service facilities. The estimated annual water requirement is about 125 million gallons. The concentration of total dissolved solids in the present water is about 1,470 ppm, and hardness is about 660 ppm. In a proposed alternative supply, the concentrations are about 750 ppm and 250 ppm, respectively. There is a need to improve the water supply due to high concentrations of total dissolved solids and sulfates and hardness. The Santa Barbara County Health Department has prohibited new water service connections until the quality of the present water supply is improved.

The lowest cost desalting process for the alternative water supply is reverse osmosis at an estimated cost of $0.80 per 1,000 gallons. No feasible alternative surface water supplies are available to this community. It may be feasible to export desalted water from New Cuyama to Old Cuyama, also located on the valley floor, 4 miles away.

Havasu. The Havasu Water Company serves water to about 200 persons in a recently developed residential community in a semiarid area near the shore of Lake Havasu. The estimated annual water requirement is about 7 million gallons. Since mid-1973, the water company has been diverting Colorado River water from the lake under leased water rights. The Company has also developed and used local brackish ground water, which, due to lack of rights to river water, is the only long-term water supply controlled by the Company. The average concentration of total dissolved solids in water from three wells is about 1,700 ppm, and the hardness is about 560 ppm. There is a need to improve the quality of the ground water supply due to the high concentrations of total dissolved solids and sulfate, both of which exceed the recommended limits set by the Department of Health, and hardness.

The lowest cost desalting process is reverse osmosis at an estimated cost of $3.70 per 1,000 gallons. This unusually high cost is due to a low load factor. The

water company must develop a reliable water supply to meet requirements of the California Public Utilities Commission if the Company is to expand its service area as planned. If a reliable supply of water cannot be obtained from the lake, desalting of the ground water will be necessary because there does not appear to be another feasible alternative.

Winterhaven. The Winterhaven County Water District delivers brackish ground water to about 200 connections. The estimated annual water requirement is about 53 million gallons. The concentration of total dissolved solids in this water is about 1,370 ppm, and the hardness is about 560 ppm. There is a need to improve the quality of the water supply due to high concentrations of total dissolved solids, manganese, and sulfates, which exceed the recommended limits set by the Department of Health, and the hardness. After a study of community conditions, the engineering consultant for Winterhaven concluded that development of adequate water supplies and sewage disposal facilities is essential for both the future development of the community and the protection of health.

The lowest cost desalting process is reverse osmosis at an estimated cost of $1.10 per 1,000 gallons. At present there does not appear to be another feasible alternative for improving the quality of the water supply.

Marin County. The Marin Municipal Water District serves surface water from local reservoirs to several thousand residents within that District. The existing water supply is of high quality, but the present demand exceeds the safe yield of present water supplies. The District is investigating alternative sources of additional water supply, including reclaimed waste water, local and imported water, and desalting of sea water either from the ocean or San Francisco Bay. The only alternative evaluation in this report is desalting of bay water by distillation; this would produce 858 million gallons of desalted water annually. The estimated cost would be $1.70 per 1,000 gallons.

Refugio State Beach. The California Department of Parks and Recreation has served brackish ground water to users of this recreation area on the coast of Santa Barbara County. The estimated annual water requirement is about 3.6 million gallons. The concentration of total dissolved solids in this water is about 1,910 ppm, and the hardness is about 1,470 ppm. There is need to improve the water supply for this area due to both high concentrations of total dissolved solids and hardness. In 1971, the California Department of Health advised the Department of Parks and Recreation that this water should no longer be used for human consumption.

The lowest cost desalting process that would improve the quality of the ground water is reverse osmosis at an estimated cost of $3.25 per 1,000 gallons. The estimated cost of desalting nearby ocean water by the vapor compression process, a distillation process frequently selected for small capacity applications in which steam temperature is increased by a compressor (See Figure 12), would be $5.65 per 1,000 gallons. This unusually high cost is due to the small quantity of water desalted and a low load factor. Because of the isolated location of this site, importing surface water is not feasible. Until more suitable ground water is located or desalting is used, potable water supplies will have to be trucked to the site.

Gaviota State Park. The Department of Parks and Recreation has also served brackish ground water to the users of this recreation area on the coast of Santa Barbara. The estimated annual water requirement is about 33 million gallons. The concentration of total dissolved solids in this water is about 2,650 ppm, and the hardness is about 1,010 ppm. There is need to improve the water supply for this area due to both high concentrations of total dissolved solids, which exceed the recommended limits set by the Department of Health, and hardness in the water supply.

The lowest cost desalting process that would improve the quality of local ground water is reverse osmosis at a cost of $1.00 per 1,000 gallons. The estimated cost of desalting ocean water by vapor compression is $2.40 per 1,000 gallons. These costs are lower than those for Refugio Beach due to a larger scale of development and a much higher plant factor. Because of the isolated location of this site, importing surface water is not feasible. Until more suitable ground water is located or desalting is used, potable water supplies will have to be trucked to the site.

Environmental Impact

The types and amounts of energy required for each desalting application and the resulting impact on the environment are essential considerations for each desalting application. The amount and type of energy required vary with the desalting applications. Where excess salinity is a water supply problem and other water supply alternatives are not feasible, desalting may be the only alternative.

The environmental impact of construction and operation of the desalting facilities could be minimized through design of facilities, location, use of paint, and screens of natural growth. In the assessment studies, disposal of brine is by evaporation in open-lined basins or discharge into saline water. Measures could be applied to prevent degradation of water supplies and surrounding land by the brine or unacceptable disturbance of wildlife habitat.

Cost Information

Cost data are summarized in Conclusion No. 3 and are presented in Chapter 4 and in more detail in Appendix A, "Cost Estimates and Possible Sources of

Financing". In some instances, financing of the required facilities may represent a problem. Where local financing cannot be obtained, financial aid that may be available is briefly discribed in Appendix A.

Benefits

The benefits of providing a better quality water supply will vary according to conditions in each community. The benefits considered in this study, as discussed in Chapter 4, are limited to those that would accrue to residential and commercial water uses, such as increased life of water using appliances and plumbing, elimination of water softeners, and reduced consumption of soap and cleaners. Some benefits can be readily measured in terms of dollars, whereas others are indirect and difficult to evaluate. A more general discussion of the benefits of desalting is provided in Appendix C, "Benefits Attributable to Improved Water Quality".

Conclusions

1. In 9 of the 10 communities selected for study, brackish ground water is the source of water supply and does not meet the recommended limits established by the California Department of Health because of excessive concentrations of salt.

2. The other community, Marin Municipal Water District, has a high-quality surface water supply, where the safe annual yield is less than the annual demand, and desalting is only one of the alternatives for providing and additional water supply.

3. The minimum costs of desalting water to meet the water quality requirements specified by each community are shown below. In several cases it was possible to reduce the costs by blending the desalted water with untreated local water to provide a blended water supply that met the requirements. These costs are also shown in the following tabulation:

	Desalting Costs (Dollars per 1000 gallons)	
Community	*desalted water*	*blended product*
Boron	\$1.09	\$0.70
Buellton	1.14	0.95
Greenfield	0.92	0.74
Old Cuyama	4.46	unsuitable
New Cuyama	1.31	0.56
Havasu	4.67	2.80
Winterhaven	1.17	1.08
Marin Municipal Water District	1.71	unsuitable
Refugio State Park	3.23	unsuitable
Gaviota State Park	1.06	0.95

4. A more detailed evaluation should be made of desalting to improve the water supply for the communities of New Cuyama, Havasu, Winterhaven, and the two state managed areas—Refugio State Beach and Gaviota State Park—due to the limited better quality water supply alternatives available to those communities and the essential need of improved water supply for future development.

5. In most of the communities assessed in this study, desalting to improve the quality of the water supply would result in significant benefits

6. In some communities, the local financing of desalting facilities may be a problem. In these cases, it is uncertain as to what, if any, financial aid may be available under federal or state programs. A case-by-case analysis would be a necessary first step.

7. Through use of the latest state of the art in natural environmental protection, there would be a minimum impact of the natural environment resulting from construction and operation of a desalting facility at any of the 10 communities. The most significant impact is expected to be caused by the evaporation basins used for brine disposal facilities. The facilities could be located, designed, and landscaped to cause minimum impact.

Recommendation

The Department of Water Resources recommends that the following communities consider more detailed study of desalting as a means of providing good quality water supplies:

a. New Cuyama

b. Havasu

c. Winterhaven

d. Refugio State Beach

e. Gaviota State Park.

II. INTRODUCTION

This study is an engineering assessment of desalting techniques that might be used to provide good-quality water supplies in the 10 small and medium-size California communities shown in Figure 2. In each community, excess salt in municipal water supplies, in possible supplemental supplies suggested by the communities, or in waste water resulting from use of these supplies, has created a problem. Bulletin No. 193 describes how each community might use desalting to provide good-quality water supplies and thus upgrade the quality of life in general.

Scope

The study was conducted as a reconnaissance-level, or preliminary, assessment that will enable these communities to evaluate the costs and benefits of certain desalting processes. This preliminary information will further enable each community to determine whether desalting might indeed be beneficial. However, even if this preliminary assessment indicates that desalting may be the answer to a particular water supply problem, a more detailed analysis would be essential before any of the 10 communities commits itself to the construction of desalting facilities.

This bulletin discusses:

1. The method by which the 10 communities were selected for study.
2. The specific water supply problem in each community.
3. A desalting process, and the facilities required to carry it out, that might be used to improve the quality of water supplies in each community
4. The benefits of improved water supply that would accrue to each community.

The bulletin also presents estimated costs of the various desalting applications. The term *desalting application* includes (1) the required pretreatment of the raw water supply, (2) the desalting process, and (3) the disposal of remaining brine. The estimates provided in this report do not include the cost of a distribution system but only the cost of water at the downstream side of the desalting plant. These costs are preliminary and are presented to assist in decision making, but are not intended to be the basis for determining final funding requirements or repayment negotiations. If these preliminary estimates indicate that desalting may be practical in a given community, more detailed cost data and exact cost information from manufacturers would be required to establish final estimates. Additional information on both costs and possible sources of financial assistance are presented in Appendix A.

Regardless of the method of desalting used, the raw water used as a source of supply (feedwater) will require some pretreatment. Each desalting facility must be designed for certain feedwater conditions, e.g., mineral content, hardness, acidity, temperature, etc. After desalting, some additional treatment may be needed before the product water can be distributed. Moreover, the substantial quantities of brine produced will require an acceptable means of disposal. The pretreatment of feedwater, posttreatment of desalted water, and disposal of brines are discussed in some detail in Appendix B, "Pretreatment, Posttreatment, Storage, and Disposal of Brines."

Expected benefits, both direct and indirect, for each community are also discussed. However, because the scope of this study is limited, many of the benefits cannot be precisely measured in dollars; such benefits would require study in greater depth to develop a meaningful dollar evaluation. In addition to the discussion of specific benefits in each community, a broad discussion of the overall benefits of desalting is provided in Appendix C.

The water quality problems discussed in this bulletin, which are based on mineral analyses of local water supplies in each community, are limited to those that could be resolved by desalting. Both the Federal Government and the State of California have developed standards for suppliers of domestic water. Both sets of standards are essentially the same.

Title I, Part 1, Chapter 5 of the California Administrative Code states

> "It is the responsibility of each water supplier to exercise due care and diligence to protect the water sources under his control. . .and to take whatever investigative or corrective action is necessary to assure that a pure, wholesome, and potable water is continuously supplied to users . . ."

Standards pertaining to permissible limits of mineral concentrations in domestic water supplies, as set forth in Chapter 5 of the California Administrative Code, are presented as Appendix D, "Quality Standards for Domestic Water Supplies".

Purpose of Study

The general objective of this study is to assess, at a reconnaisance level, desalting applications to provide good-quality water supplies for 10 California communities. The communities were selected from those in the inventory, which primarily included

small and medium-sized, isolated California communities where desalting might be used within the next 5 years to (a) improve the quality of existing water supplies, (b) provide supplemental fresh water, or (c) facilitate the disposal of waste water. Nine of the communities represent various types, e.g., agricultural, nonagricultural, desert, coastal, recreation-oriented, and one is part of a metropolitan area. These improved water supplies would be used in homes, industries, and commercial establishments, but would not be used for irrigated agriculture.

Of special interest to California is the evaluation of desalting techniques that would provide good-quality water supplies in such communities. The State has a continuing interest in developing and improving the management of water resources, including surface water, ground water, reclaimed waste water, and, in certain coastal areas, the desalting of sea water.

The States's interest in reclaimed water includes (1) the direct use of treated waste water for nondomestic purposes, or its indirect use through recharge of ground water; and (2) the removal of dissolved salts in waste water to meet the requirements set by the State Water Resources Control Board for discharge into the State's waterways. Desalting processes that will accomplish both of these goals are now available.

Of special interest to the Office of Saline Water was the feasibility of medium-size desalting applications in communities where water quality has been impaired by excessive concentration of salts. Since 1952, the Office of Saline Water has devoted considerable financial support to the development of processes and equipment that will remove dissolved solids from water, and has supported a number of similar studies in other states which have demonstrated that desalting is a practical method for improving the quality of brackish water.

Background

Overall, California has an abundant supply of both surface and ground water. However, the wide disparity in distribution of the available surface water has resulted in severe water deficiencies in some parts of the State. In general, the greatest quantities of surface water are available in areas with the fewest people—the North Coastal Area and the Sacramento Basin. As a result, large-scale transfer systems, such as the recently completed first phase of the State Water Project, have been constructed to transport surface water from areas of surplus to areas of need.

In most of the State's surface water, the concentration of salts, which is a determining factor in the evaluation of water quality, and thus its usability, is relatively low. However, in Southern California, large quantities of surface water are imported from the Colorado River. In 1970, the concentration of total salts in the Colorado River at Parker Dam was about 750 parts per million (ppm), considerably higher than the maximum of 500 ppm recommended for drinking water by the U. S. Public Health Service. Moreover, predictions of the future quality of Colorado River water at Parker Dam, based on the expected development of upstream projects, indicate that its average salinity will increase to about 1,000 ppm by 2000.

Ground water, also an important source of water in California, provides about 40 percent of the State's water supply. Ground water can be found in almost any part of the State; however, production rates per well vary widely—from a few gallons to several thousand gallons per day—and in some parts of the State, the ground water is so brackish that it is all but unusable.

The concentration of salts in ground water varies in different parts of the State and frequently varies with the depth below ground surface. In general, the concentration of salts in ground water exceeds that of surface water in the same area. When various community water supplies were inventoried for this study, the highest concentration of total dissolved salts (TDS) in ground water was about 9,500 ppm—greatly exceeding the level of 500 ppm recommended by the U. S. Public Health Service. However, such water would rarely be used. In this survey of communities, the highest TDS concentration in ground water used regularly was about 4,300 ppm (at Old Cuyama in Santa Barbara County).

Most poor-quality ground water is found in the southern half of the State. In some cases, the inferior quality results from high concentrations of specific salts; in others, from high concentrations of total salts. In many California communities, this high salt concentration in ground water restricts its use for municipal water supplies. Some of these communities have solved the problem through imports of surface water. Others, however, have been unable to avail themselves of water transfer projects. Some communities are too distant from project facilities, others lack the financial resources, and still others have been unable to develop sufficient community interest and support.

Associated with the cost of water in these communities are such hidden costs as the purchase of excessive washing powders, soaps, water softeners, bottled water, etc., and such intangible costs as corroded plumbing systems and shortened appliance life. These costs are often difficult to evaluate in terms of dollars. The industrial and commercial use of highly mineralized water frequently results in additional hidden costs.

With today's rapidly expanding knowledge of and interest in public health, many communities are demanding that their water supplies be (1) free of toxic

and corrosive substances, (2) free of harmful organic and biological matter, (3) without objectionable taste or odor, and (4) clear and colorless. As a guide to the acceptability of water supplies, the California Department of Health has provided standards for levels of bacteriological, physical, chemical, and radiological constituents. Appendix D, "Quality Standards for Domestic Water Supplies", presents standards governing the mineral content of domestic water supplies.

Most physical and bacteriological constituents can be removed by filtration and coagulation. However, with the exception of the hardness ions, i.e., bicarbonates and some phosphates, such treatment processes will not remove dissolved salts. On the other hand, the capabilities of today's desalting processes range from the removal of particular ions to the removal of essentially all dissolved substances except gases.

Desalting Technology

During recent years, desalting technology has shown marked improvement. New processes have been introduced, and previously developed processes have been upgraded. These improvements have reduced the rate of increase in costs of desalting, even in this day of escalating costs. One example of such a process is reverse osmosis, which during the 1960's was still in the laboratory stage. Today, reverse osmosis is widely used for a number of desalting tasks. Other widely used desalting processes include distillation, electrodialysis, and ion exchange.

To provide a desalting plant of the capacities discussed in this bulletin would require from 1 to 2 years between approval of a contract with an equipment manufacturer and the production of desalted water. A skid-mounted reverse osmosis unit could be ready for production in about 1 year from the contract date. Construction of a distillation unit on site would require from 1 to 2 years.

For the 10 communities considered in this report, 5 types of desalting processes were evaluated. Where local water supplies were brackish, reverse osmosis, electrodialysis, and ion exchange were considered. In three of the communities, where the source of water would be the ocean or San Francisco Bay, two distillation processes—vertical tube evaporation and vapor compression—were included in the analyses.

Except for a vertical tube evaporation plant, each of the desalting facilities discussed in this report is small enough to be mounted on a skid. Each could be assembled by the manufacturer and delivered as a unit to the operational site. Each could be designed to accommodate additional modules if additional future capacity were considered a possibility.

The five desalting processes considered in this study are briefly discussed in the following paragraphs.

Reverse Osmosis

Ordinarily, if fresh water and brackish water are separated into compartments by a semipermeable membrane, the fresh water will pass through the membrane by osmosis, which is the natural process of equilization of solutions, and dilute the brackish water. However, if pressure is exerted on the saline solution, the osmosis process can be reversed. When the pressure on the brackish water exceeds the natural osmotic pressure, fresh water from the brackish solution will pass through the membrane to the freshwater side, leaving the salts in a concentrated brine. Figure 3 is a flow diagram of a typical reverse osmosis installation.

The higher the salt concentration in the feedwater, the higher the pressure required, and, as the pressure is increased, the stronger the membrane required to prevent the passage of salts. At the present time, membranes strong enough to withstand the very high pressures required to desalt sea water have been developed for use in the laboratory. The four common membrane arrangements—plate and frame, tubular, spiral wound, and hollow fiber—are shown in Figure 4. A typical apparatus is presented in Figure 5.

When water contains a high proportion of sulfates or carbonates that cause scale on the membrane surface and when a high recovery of product water from the feed water is desired, pretreatment of the feed water is necessary. In connection with a test program for desalting agricultural waste water, the Department at its Waste Water Treatment Evaluation Faciliy is using an ion exchange softening process as a pretreatment for the feed water to experimental reverse osmosis units. With this ion exchange pretreatment, we have been able to recover by reverse osmosis desalting 90 percent of the water from the feed. The feed water contains about 6,000 parts per million TDS and has a high concentration of sulfate. This pretreatment of reverse osmosis feed water by ion exchange softening is still experimental. The combination was, therefore, not considered for the applications described in this bulletin.

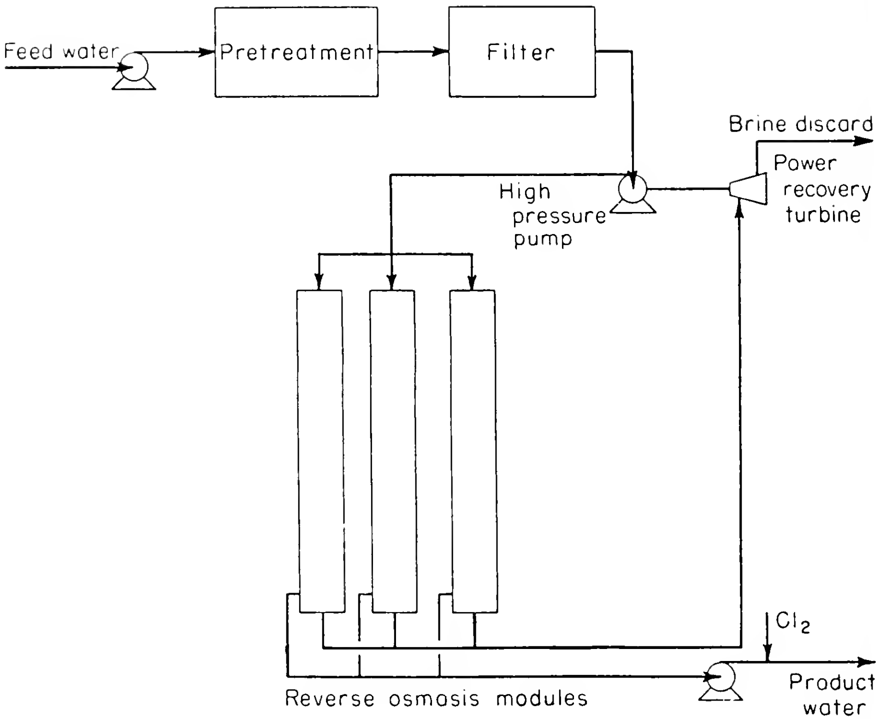
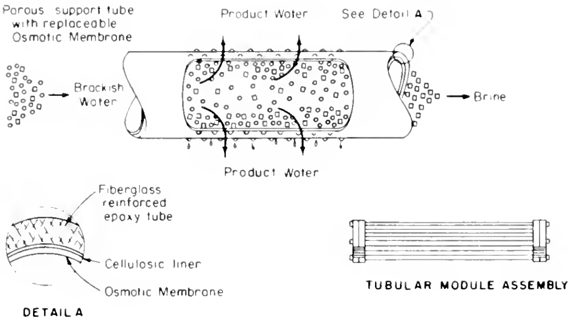
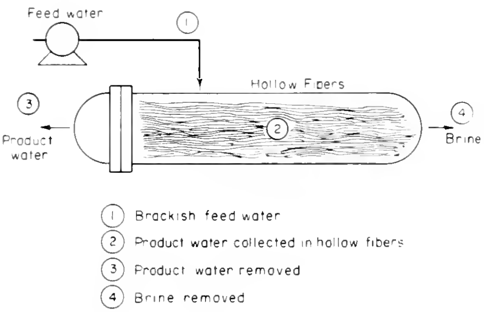


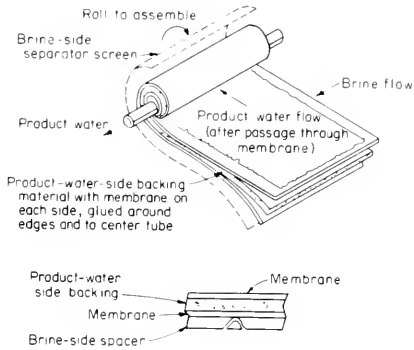
Figure 3. Schematic Diagram of Reverse Osmosis Desalting Process



Tubular Module Configuration



Hollow Fine Fiber Module Configuration



Spiral Wound Module Configuration

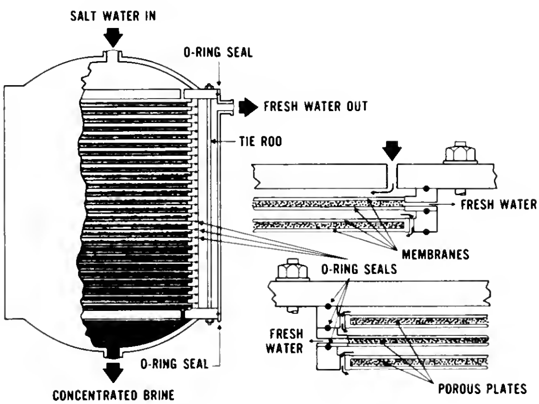
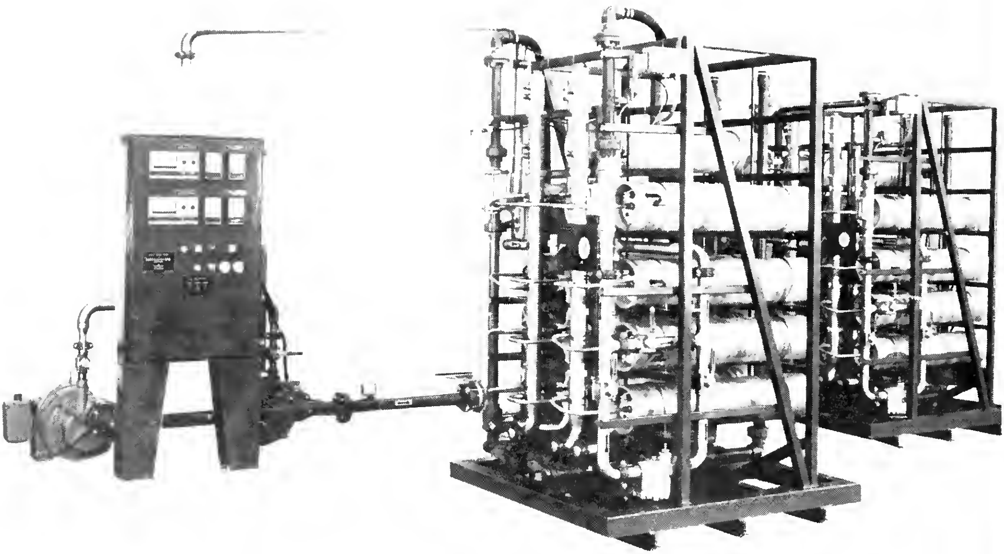
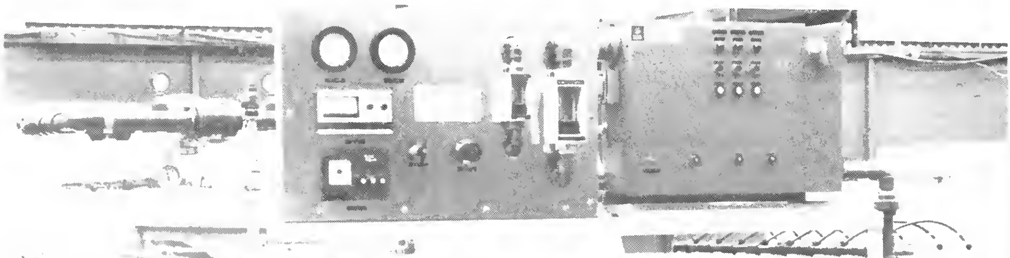


Plate and Frame Configuration

Figure 4. Four Common Membrane Arrangements for Reverse Osmosis Process



Courtesy of Polymetrics



Courtesy of Envirogenics Systems Company

Figure 5. Typical Apparatus for Reverse Osmosis Process

Electrodialysis

Electrodialysis combines the use of an electrically charged cell and ion-selective semipermeable membranes to remove salts from brackish water. When a salt dissolves in water, it tends to break down into ions. Positive-charged ions, such as sodium, are called cations; negatively charged ions, such as chloride, are called anions.

As mineralized water is passed through an electrodialysis cell, the cations are attracted to a negative electrode and the anions are attracted to a positive electrode. Two types of membranes are used. Cation-permeable membranes permit passage of cations only, such as sodium and calcium. Anion-permeable membranes permit passage of anions only, such as chloride and sulfate.

In actual practice, a large number of membranes can be placed between the electrodes, forming a number of dilute (demineralized) compartments and concentrate (brine) compartments. With the salt ions removed from the influent water, desalted water flows out of the cell (as shown in Figure 6). A typical installation (stack) 48 inches high, 18 inches wide, and 40 inches long contains as many as 640 membranes. A typical apparatus is shown in Figure 7.

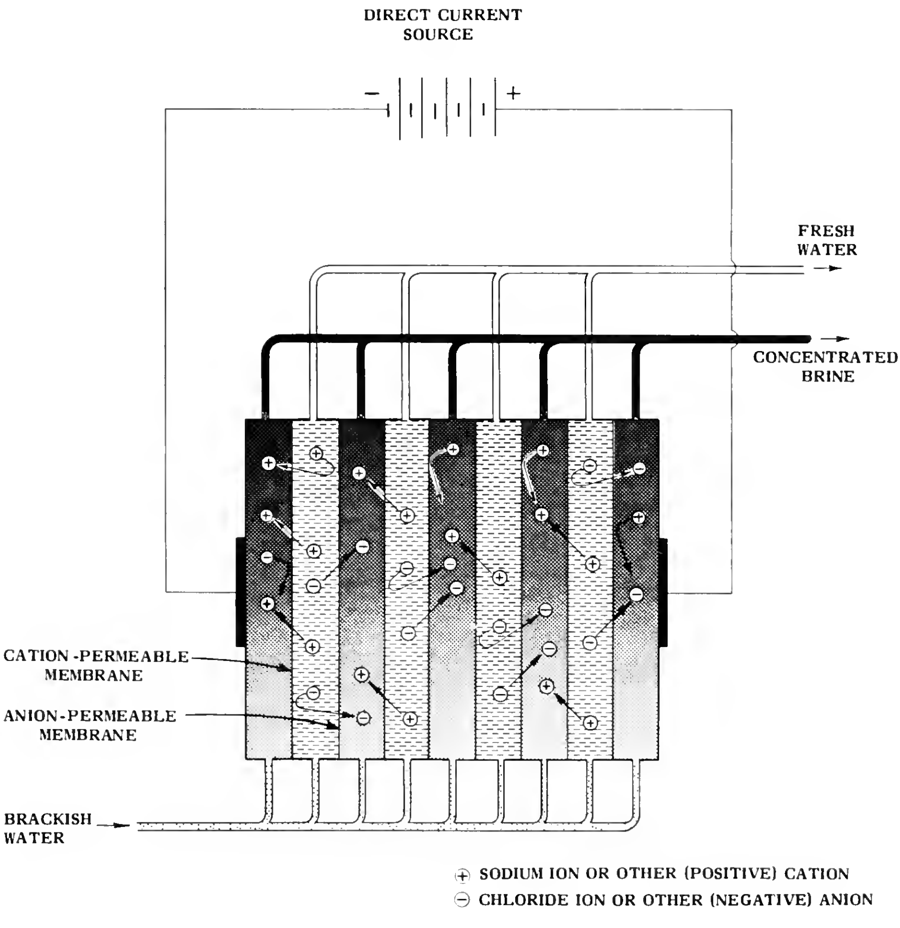
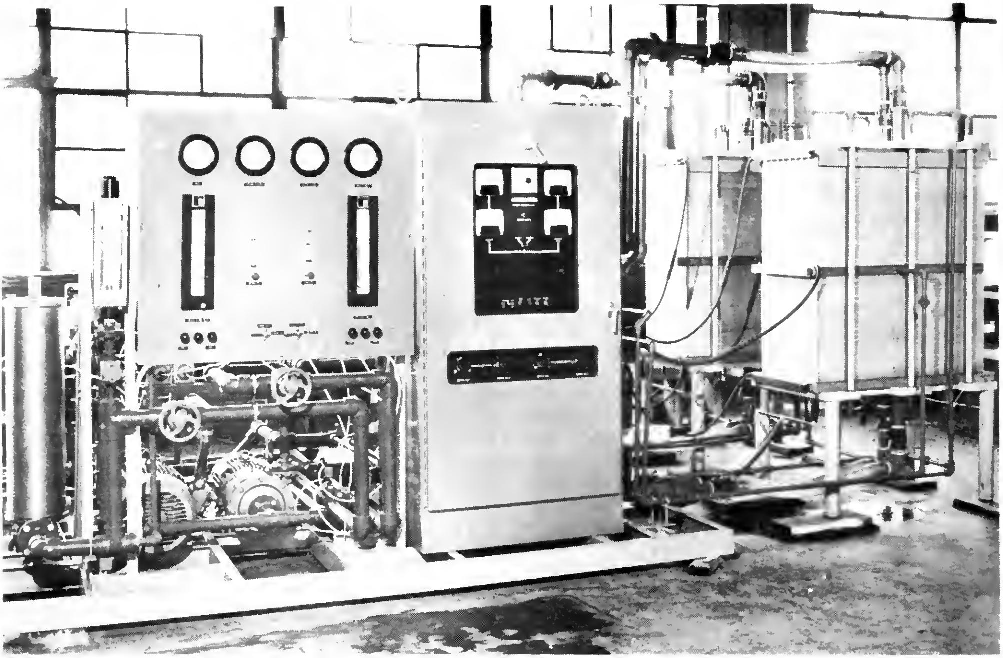


Figure 6. Schematic Diagram of Typical Electrodialysis Process



Courtesy of Ionics, Inc., and F&F Industries

Figure 7. Typical Apparatus for Electrodialysis Process

Ion Exchange

An ion exchanger is a porous bed of natural material or synthetic resins that have the ability to exchange ions held in the resin with those in the mineralized waters that contact the bed. In the ion-exchange process, both cation and anion exchangers are used. The beds are usually placed in series so that the mineralized water passes first through the cation exchanger and then through the anion exchanger.

In the cation exchanger, cations, such as sodium, are taken from the mineralized water, and a hydrogen ion is put into the water. In the anion exchanger, anions, such as chloride, are taken from the water, and a hydroxide ion is put into the water. Thus, sodium chloride is removed from the brackish water, leaving demineralized water for use. In addition, the hydrogen and hydroxide ions combine to form more water, thus adding to the volume of fresh water produced.

As the conversion process continues, the resins become increasingly saturated with the ions and finally lose their ability to remove the various ions in the mineralized water. At this point, the resin beds must be regenerated with acid and caustic to restore their ion-exchange properties. The chemicals used to regenerate the resins, and the ions removed from the resins during regeneration, increase the wastes requiring disposal.

A flow diagram of the ion exchange process is shown in Figure 8. Figure 9 is a typical ion exchange installation.

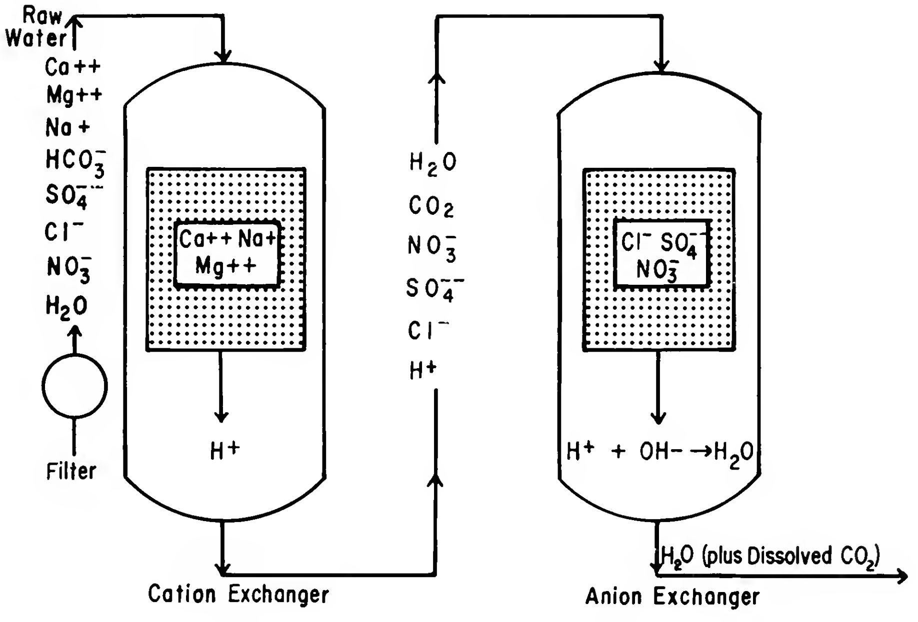
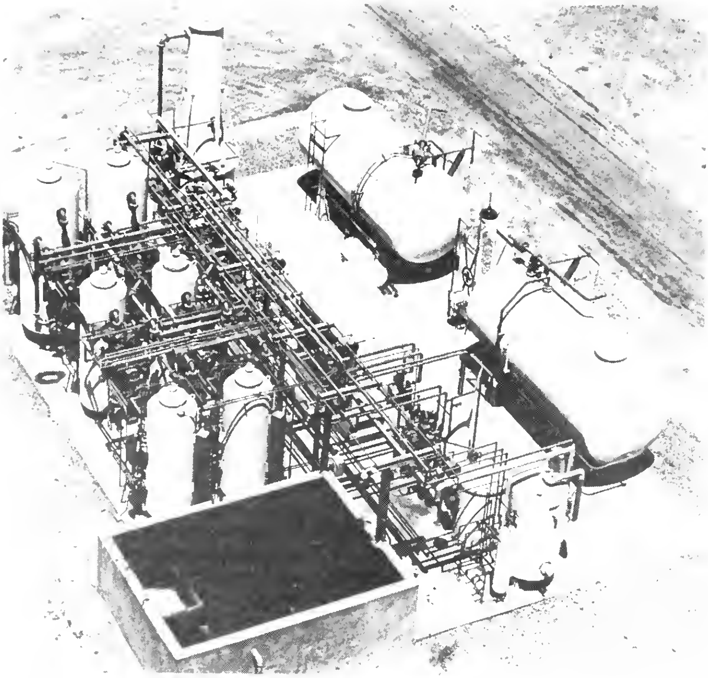


Figure 8. Schematic Diagram of Ion Exchange Process



Photos Courtesy of CHROMALLOY - L*A/Water Treatment Division

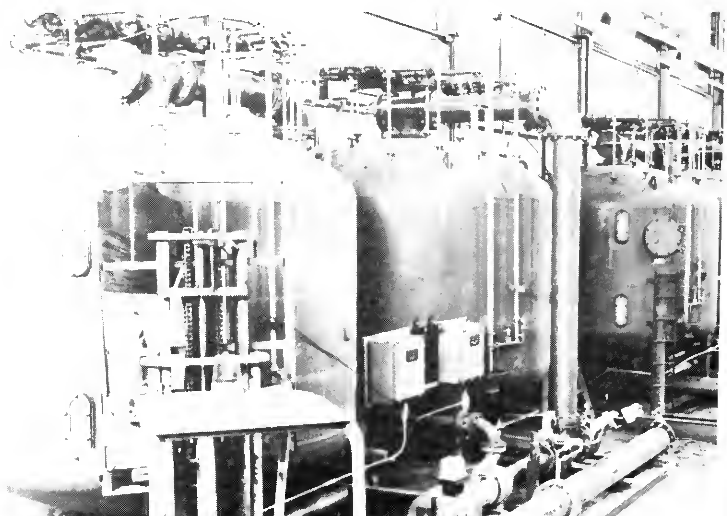


Figure 9. Ion-Exchange Desalting Plant and Close-up View of Resin Tanks

Vertical Tube Evaporation

Vertical tube evaporation is a distillation process generally used for desalting water of high salt concentrations, such as sea water (average TDS, 35,000 ppm). In vertical tube evaporation, or distillation, the saline water is passed through a series of large, interconnected vertical chambers (called "effects"), where part of the saline water is converted to steam (evaporated) and then condensed as salt-free water.

The preheated saline water enters the effect, and, as it falls through the tubes, it is heated by steam that envelops the tubes, This heat-exchange operation converts some of the water from the saline solution inside the tubes into steam, and simultaneously condenses some of the steam that surrounds the tubes into fresh water.

To obtain high efficiency in the recovery of heat energy, the process is repeated in several effects, which are arranged in series. The steam for the first effect is supplied by a steam-generator plant, and the condensed water from the first effect is returned to the steam-generator plant to be reconverted into steam. Steam generated inside the tubes of the first effect flows to the second effect, where it surrounds the second bundle of tubes. The brines not vaporized in the first effect are pumped to the top of the second effect and flow downward through the second tube bundle, and the process is repeated through several effects until most of the heat energy supplied in the first chamber is recovered.

A diagram of the vertical tube evaporation process is shown in Figure 10. Figure 11 shows a typical pilot-plant installation.

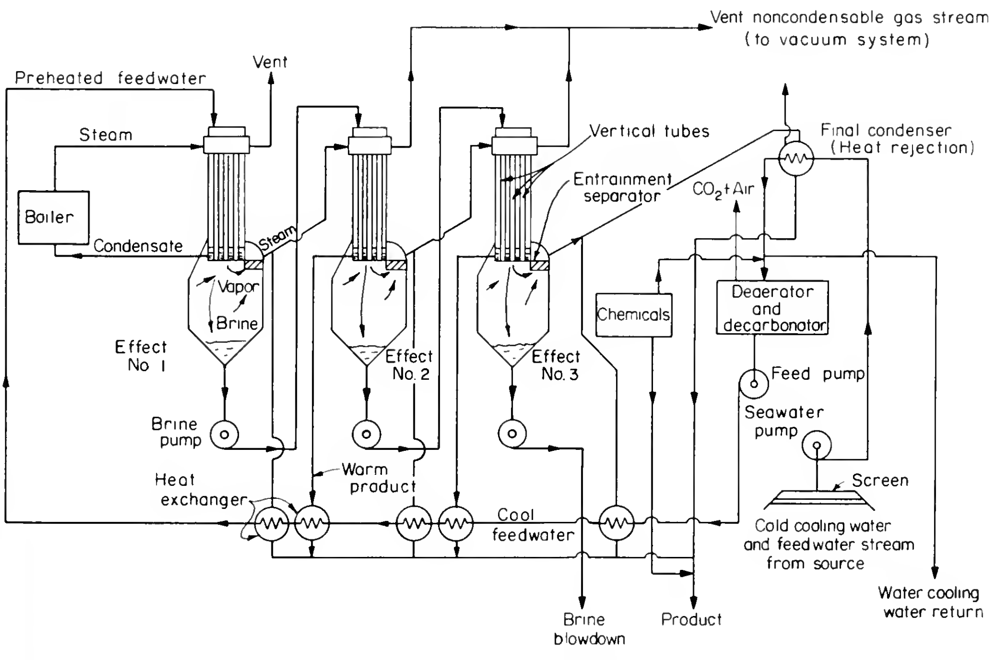
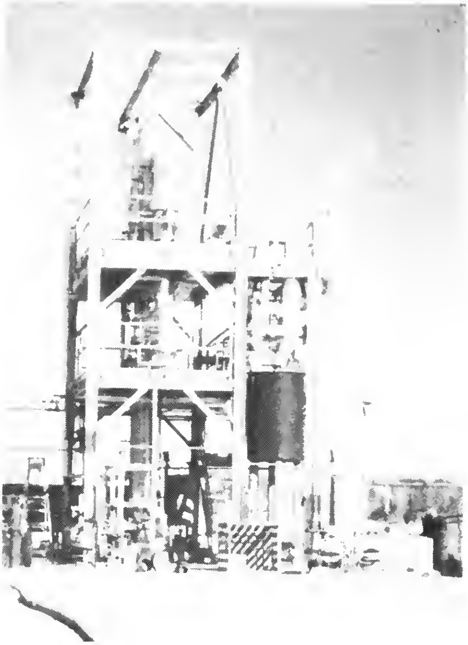


Figure 10. Schematic Diagram of Typical Vertical Tube Evaporation Process



Courtesy of U. S. Bureau of Reclamation

Figure 11. Typical Apparatus for Vertical Tube Evaporation Process (Pilot Plant)

Vapor Compression Distillation

When a vapor in compressed, its temperature and pressure increase and its volume decreases. The use of this principle has been incorporated into vapor compression distillation of sea water. In vapor compression distillation (Figure 12), saline water is pumped into a large chamber. As the feedwater passes into the chamber, it is heated by steam, and the transfer of heat within the chamber causes some of the feedwater to vaporize.

The vapor is then drawn off by a compressor and returned through a tube to the chamber, where it loses heat, by condensation, to the incoming feedwater. As the vapor condenses, it is drawn out of the chamber as salt-free water. The incoming saline water vaporizes, passes to the compressor, and the cycle is repeated.

The primary difference between vapor compression and other distillation processes is that a separate source of steam heat is required only for start-up. The process converts mechanical energy to produce its own heat and thus eliminates the need for a large steam generator. The vapor compression unit is compact and is available in sizes that produce relatively small amounts of product water. Vapor compression distillation is used to provide drinking water on ships, in island communities, and on offshore oil platforms.

A diagram of the vapor compression process is shown in Figure 12. Figure 13 is a typical apparatus.

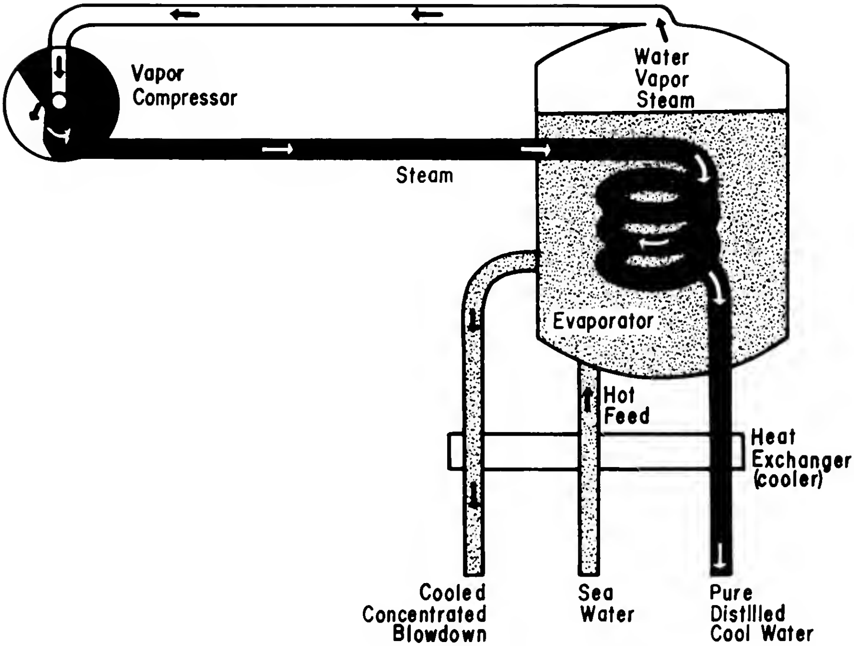
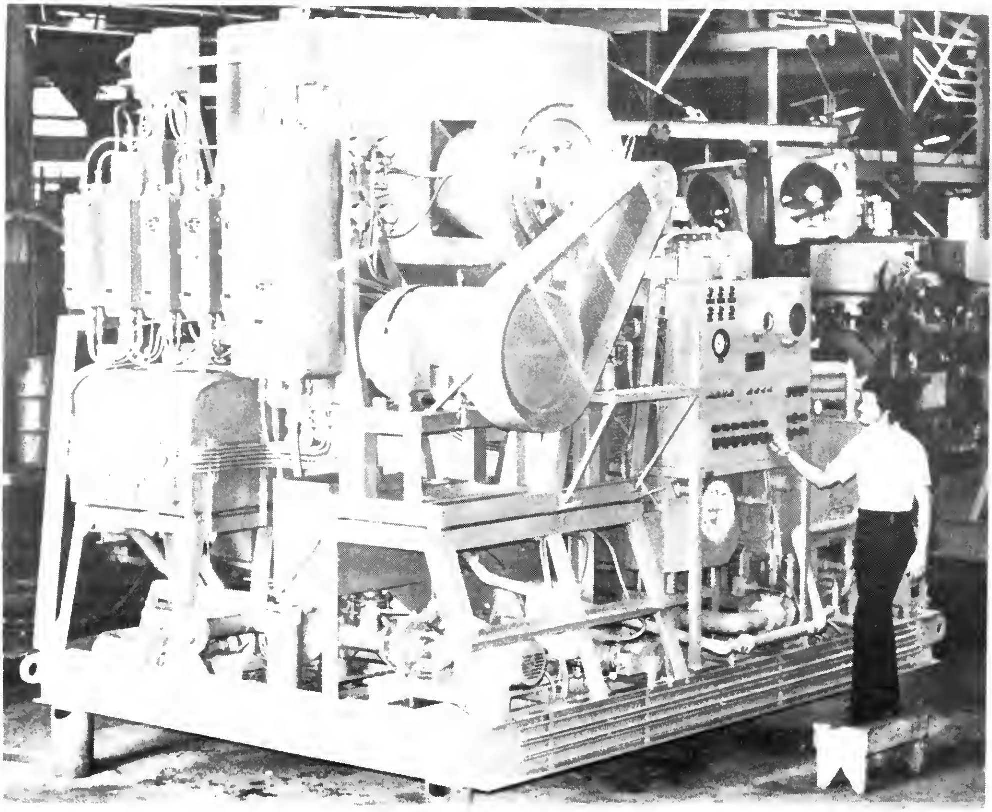


Figure 12. Schematic Diagram of Typical Vapor Compression Distillation Process



Courtesy of Mechanical Equipment Company

Figure 13. Typical Apparatus for Vapor Compression Distillation Process (50,000 gpd output)

Factors in Desalting Process Selection

Several factors must be considered when determining the desalting process to be used for a given application. However, some general statements can be made as to which desalting processes are likely to be most favorable when desalting certain feed waters. The following are taken from "Desalting Hand-

book for Planners", U. S. Department of the Interior, May 1972.

"... the most favorable feed water salinities for practical application of the various desalting processes are approximately as follows:

Distillation processes	10,000–50,000 ppm
Freezing	5,000–50,000 ppm
Electrodialysis	1,000– 5,000 ppm
Reverse osmosis	1,000–10,000 ppm
Ion exchange	0– 2,000 ppm

For the purpose of cost comparison, feed water salinities outside these ranges could be considered when particular circumstances so indicate. For instance if extraordinarily high or low product concentrations are required the cost picture could change considerably."

The handbook shows the approximate capital cost, energy costs, and other costs as a percentage of total costs for various processes. These are as follows:

Process	*Size of Plant Considered*	*Capital Costs*	*Desalting Plant* *Energy Costs*	*Other Costs*
Membrane				
Reverse Osmosis	10 mgd	23%	12%	65%[1]
Electrodialysis	10 mgd	25%	18%	57%[2]
Thermal				
Multistage Flash	50 mgd	33%	47%	20%
Vertical Tube Evaporator—Multiple Flash	50 mgd	27%	54%	19%
Vapor Compression—Vertical Tube Evaporator—Multistage Flash	8 mgd	40%	21%	39%

[1] Includes 32% for supplies and maintenance materials mostly for membranes

[2] Includes 15% for membrane replacement costs

The percentages are indicative only as to the proporton of cost that might be expected for capital and energy for any given situation. These values were developed for specific conditions and may not be valid for plants of other capacities operating under different conditions. A case-by-case evaluation is necessary to determine the relative capital or energy intensity of each application.

III. SELECTION OF STUDY AREAS

The 10 areas finally selected for study varied from a desert community in southeastern California to a state beach on the Pacific Coast. The selection procedure is briefly described in the following paragraphs.

First, isolated California communities with municipal water supplies containing excessive minerals were inventoried. Communities were selected for the inventory by a comparison of local water quality with standards established by the U. S. Public Health Service. All communities with water supplies of substandard quality were included; however, the final selection of study areas was based on such factors as (1) type of community, (2) location, (3) degree and type of water quality problem, and (4) community interest in water quality improvement.

Inventory of Communities

The inventory was conducted through a search of water quality data in the files of the California Department of Water Resources and through discussion with representatives of county health departments, the California Department of Health, and the California Regional Water Quality Control Boards.

Criteria

The following criteria were used to select communities to be included in the statewide inventory:

1. Location in any part of the State
2. Excessive concentration of salts in (1) existing water supplies, or (2) supplemental water supplies, or (3) waste water.
3. Isolation from sources of supplemental water of satisfactory quality that could be blended with or replace existing poor-quality water supplies.
4. Water supplies must be improved during the next five years. Present water supplies sufficiently poor to require immediate improvement, or indication that improvement would be needed within five years.
5. Water supplies used for nonagricultural purposes. Waste waters considered excluded industrial or agricultural wastes
6. Water supplies of substandard quality were identified by comparison with the following standards recommended by the U. S. Public Health Service and the California Department of Health:

Constituent	PPM
Total dissolved solids	500
Chloride	250
Sulfate	250
Nitrate	45
Iron	0.3
Arsenic	0.1
Mongenese	0.05
Fluoride	1.4 to 2.4

7. Although hardness in water is not included as a standard (in 6), its presence indicates a need for treatment. However, many of the communities requested that a maximum hardness of 100 ppm expressed as calcium carbonate be used as an acceptable level in treated water.

Procedure

Input from all parts of the State was developed for the inventory. This input was obtained from a survey of data on file at the Department of Water Resources and from information provided by the California Department of Health and the California Regional Water Quality Control Boards. The Department of Health grants permits to water suppliers in the State to furnish domestic water supplies and establishes requirements for its quality. The Regional Water Quality Control Boards consider discharges of waste water and establish standards for disposal into waters of the State. These agencies have the administrative power to prohibit the use of water supplies, or the discharge of waste waters, which contain excessive concentrations of salts or other pollutants.

Information in the inventory was combined into the Department of Water Resources report mentioned on page 1 ("Inventory of Small and Medium-Size Isolated California Communities With Brackish Water Supplies"). This report, which contains the complete inventory of communities, locates each city and provides data on type of water service, water source, water requirements, and water quality problems. In addition, the report provides a water quality analysis of each source of water.

Results

Most of the communities listed in the inventory are located in the southern part of the State, south of

an east-west line through Bakersfield. As shown in Figure 1, most of the Southern California communities included in the inventory are grouped in relatively few areas. The more densely populated communities in Los Angeles, Orange, and San Diego Counties meet their major water requirements by importing surface water. Communities in the desert area of southeastern California are widely scattered, and no surface water is used except along the Colorado River and in central Imperial and Riverside Counties, where water is imported from the Colorado River.

In Central California only a few communities, all of them located on the floor of the San Joaquin and Salinas Valleys, were included. The easternmost and westernmost portions of central California are mountainous, and the communities located there are small and generally have good-quality water supplies. In the San Joaquin Valley, most communities have been developed where good-quality ground water is available. In addition, some of these communities are receiving good-quality imported water.

Only a few isolated, individual wells in Northern California were included in the inventory; these are located on the floor of the Sacramento Valley and in eastern Lassen County. The poor-quality ground water in Lassen County is principally due to geothermal activity. The communities in the far northern part of the State, which is rich in good-quality ground and surface water, generally have adequate water supplies available at reasonable costs.

A few communities near San Francisco Bay and on the adjacent coast were included in the inventory. Only one Bay area community uses brackish ground water for municipal water supplies. The other communities have considered desalting either saline water from San Francisco Bay or sea water as alternative supplemental sources of fresh water.

A variety of communities are represented in the inventory. Two are state recreation areas at ocean beach sites, where further development is planned. At both sites, present water supplies consist of brackish ground water. Other communities in the inventory varied from isolated desert towns to coastal communities, with populations ranging from a few persons, to medium-size urban areas including mobile-home and retirement communities. In some of these communities, water is supplied by small companies operated by one person; in others, by larger municipal districts.

The water quality problems affecting most of these communities also vary. In some, the problem is a high concentration of total dissolved solids; in others, high concentrations of specific salts are the problem; and in still others, the water is excessively hard. In the inventory, the highest concentration of dissolved solids in water distributed to users is about 4,300 ppm.

In certain communities included in the inventory, where water supplies had been derived from wells delivering water of substandard quality, new wells have been developed to deliver water of suitable quality. In such cases, community water supplies were considered adequate. However, should water demands in these communities continue to increase, the substandard ground water might be upgraded by desalting and used as a supplemental water supply.

Final Selection

Within the resources available for the assessment of desalting applications in these communities, 10 was considered the maximum number that could effectively be studied. Criteria for the final selection were determined jointly by representatives of the Department of Water Resources and the Office of Saline Water.

The inventory was first narrowed to 20 communities by application of the criteria listed in the following paragraphs. Then, through direct contact and discussion with representatives of these communities, the final 10 were selected.

Criteria

These are the criteria used in the final determination:

1. The degree of need for improvement in the quality of water supply or waste water.
2. Community interest in improvement of water supplies.
3. Demands by regulatory agencies for improvement of water supplies.
4. Benefits offered by desalting.
5. Availability of alternative supplies.
6. Hardness in water supplies.

Results

The 10 study areas selected for assessment consisted of five communities with brackish ground water; two that discharge brackish waste water; two state recreation areas with brackish ground water; and one water district serving several communities that might use treated sea water as a supplemental water supply. The 10 communities are shown in Figure 2 and described briefly in the following paragraphs:

1. *Boron* is a desert community in Kern County with a population of about 2,500. The community is a residential area for employees of nearby industries. The water supply is brackish ground water.
2. *Buellton* population 1,600, is located in Santa Barbara County. Although situated in a coastal valley, Buellton is not an agricultural community.

The water supply is hard ground water containing excessive manganese and iron, which cause discoloration. The use of residential water softeners has produced highly mineralized waste water, and the California Regional Water Quality Control Board, Central Coast Region, has ordered Buellton to reduce the concentration of salts in its waste water before disposal.

3. *Greenfield* is a coastal valley agricultural center in Monterey County, with a population of about 3,000. The water supply is hard ground water, which creates a problem of waste water disposal. The Regional Water Quality Control Board, Central Coast Region, has ordered Greenfield to reduce the concentration of salts in its waste.

4. *Old Cuyama* is an interior valley agricultural community in Santa Barbara County with a population of about 55. The water supply is highly brackish ground water. The California Department of Health is questioning the use of this water by the community.

5. *New Cuyama* is located in the same valley, about 4 miles from Old Cuyama, with a population of about 800. The water supply is brackish ground water. For about 20 years, the community was a residential area for employees in nearby oil and gas fields. Just recently, however, the Foundation for Airborne Relief purchased New Cuyama. This nonprofit organization has been flying global mercy missions from Long Beach, California since 1967. New Cuyama will now be world headquarters for the foundation and a disaster relief technology research center. The foundation also proposes to establish a fly-in community at New Cuyama.

6. *Havasu* is a desert community of mobile homes and other residences for retired persons or for weekend use, with a population of about 220 (on weekends). The community, located in San Bernardino County, is near Lake Havasu, a reservoir on the Colorado River. The water supply is brackish ground water. The California Department of Health has issued Havasu a temporary permit to supply domestic water supplies, with the provision that water quality must be improved.

7. *Winterhaven* is a nonagricultural desert community, population about 900, on a main highway connecting the Southern California coast with Arizona. The California Department of Health has recommended that this community improve its waste water disposal system. Plans are also pending to improve the highly mineralized local water supplies.

8. *Marin Municipal Water District* is a water purveyor in Marin County serving several communities on the northwest shore of San Francisco Bay. The present water supply for this district is surface runoff. However, the demand for water in the district service area exceeds the safe yield of the present supply. To extend or supplement its present water supply, the district is currently considering the conservation of present water supplies, further development of fresh water, reuse of waste water, and desalting. To further evaluate desalting, the district expressed a desire to be included as one of the 10 communities considered. This study area stands apart from the other nine for the following reasons:

   a. Desalting is already being considered as a possible alternative by the District;

   b. Desalted water might be used conjunctively with local fresh surface water;

   c. The service area could be a group of small and medium-size communities; and

   d. This application of desalting would be of a different size and type than those in the other service areas.

9. *Gaviota and (10) Refugio* are the two state recreation areas administered by the Department of Parks and Recreation; each is in a different stage of development. At each area, improvement of water quality is part of the development plan. Although sea water is close at hand, the facilities required for desalting and for discharge of brines into the ocean will require special consideration to prevent environmental problems. At each area, a poor-quality brackish well is the only water supply. Because of the inferior quality water, the California Department of Health limited use of Refugio State Beach during 1972.

IV. EVALUATION OF DESALTING APPLICATIONS

For each of the 10 communities included in the tudy, the most practical desalting applications to rovide good-quality water supplies were evaluated. s explained in Chapter II, the desalting application ncludes (1) pretreatment of the raw water supply, 2) the desalting process, and (3) disposal of brine. his chapter discusses (for each community) releant community conditions, available water supplies, esalting applications, benefits, and the feasibility of esalting.

The results of this preliminary study are not inended to provide the sole basis for a decision on the pplication of desalting to improve water quality. ather, this assessment is to be used to determine hether a more detailed study of a particular desalting application is warranted.

Preliminary Information

Much of the cost data for construction, operation, nd maintenance of desalting facilities, and parameers affecting those facilities, were obtained from the ffice of Saline Water publicationn "Desalting andbook for Planners". Other supplemental infornation was obtained from the water agencies servng the various communities, equipment suppliers, nd personnel of both the Department of Water Reources and the Department of Parks and Recreaion.

A 5.5-percent interest rate was used for amortizaion of project costs and interest during construction. he useful operating life of all desalting plants was onsidered as 30 years, even though some of the lant components have shorter lifetimes. To comensate for this difference in plant life, the costs used or components with a useful life of less than 30 years ere adjusted accordingly.

Most of the communities had requested that their ater supplies be desalted to levels of (1) 500 ppm f total dissolved solids, and (2) 100 ppm of hardness s calcium carbonate ($CaCO_3$). Accordingly, the iniial evaluations were based on the attainment of a roduct-water concentration of those levels. Howev-r, the salt concentration of brackish water can be educed to less than 500 ppm TDS by the membrane r chemical processes. Therefore, the evaluations ere refined to include the blending of such higher uality product water with untreated water as a nore efficient method of obtaining the desired conentration.

In the cost estimate tables for 9 of the 10 communiies (the exception being Marin Municipal Water District), two costs are shown for reverse osmosis and two for electrodialysis. This is because neither of these processes could be used, at a given degree of treatment, to attain the desired levels of both TDS and hardness, In these nine communities, the degree of treatment required was determined on the basis of the hardness level.

In Winterhaven, for example, the degree of treatment required to reduce TDS to 500 ppm by reverse osmosis would reduce hardness to only 204 ppm. On the other hand, the greater degree of treatment required to reduce hardness to 100 ppm would also reduce TDS to 245 ppm, a lower concentration than required for acceptable domestic water supplies, but at an increased cost of \$0.18 per 1,000 gallons of product water.

The annual plant load factor shown in the cost tables also significantly affects the unit cost of product water. The load factor is the percentage of the annual design capacity that would actually be produced by the desalter. Except for the costs of energy and brine disposal, the operating cost of a plant operated at less than full capacity will not be significantly lower than that of a plant operated at full capacity.

The unit cost of desalted water is also affected by the size (capacity) of the desalter. In most cases, for a given desalting process, the smaller the capacity of the plant, the higher the unit cost of product water.

The optimum capacities for pumping, desalting, and storage can be determined for each community but are beyond the scope of this study. A certain amount of storage will be necessary to satisfy water requirements to meet peak demands. More detailed study may indicate that increased storage capacity would enable use of a smaller capacity desalter operating at higher efficiency. The optimum system for any of the communities can be determined if further study is warranted.

The disposal of brine or waste water from the desalting process must be in compliance with various state regulations governing waste discharge and must minimize any detrimental environmental impact. The three methods considered for disposal of brines are (1) discharge into a municipal waste water disposal system, (2) depositing the brine through deep wells into subsurface aquifers, and (3) evaporation from shallow basins. At coastal sites, an additional alternative is direct discharge into the ocean.

When brine is discharged into a waste water disposal system, it may be diluted by other waste water; however, such dilution will not remove the salts. If the waste water is eventually discharged into a stream or river, the salt content may degrade the receiving water in violation of discharge require-

ments. If the waste water were used for irrigation, the high salt content would eliminate its use for certain crops. If waste water were to percolate from treatment basins or spreading grounds, the high salt content may degrade underlying ground water.

When deep wells convey the brineto deep aquifers for disposal, the aquifers must be located so that the brines cannot migrate into other aquifers containing usable water. In addition, the brines must be compatible with the formations in the aquifer, i.e., must not plug the aquifer, or the brine inflow will be impeded.

The crucial factor in disposal by evaporation is the net evaporation rate. This rate is highest in arid areas and lowest along the coast. Therefore, the most efficient evaporation basins would be in dry desert areas. Furthermore, in some desert basins, the permeability of the soil would permit percolation of fluids. However, if such fluids might percolate into usable ground water, vertical and lateral confinement of the waste fluids must be provided by artificial barriers. Although the evaporation method would leave some residue, this could be hauled to a satisfactory dump site.

For desalting sites near the ocean or other saline water bodies, such as San Francisco Bay, the brines could probably be discharged into the ocean or bay after adequate diffusion in an offshore outfall. Where waste heat is of concern, as in the distillation process, special measures must be taken to meet thermal and salinity discharge requirements established for receiving water.

Three-tap or dual water supply systems have been used in some communities where both two water supplies of significantly different qualities were available and the cost of the better quality water was considerably higher than for the poor-quality water. The poor-quality water is frequently not potable. This type of system was not evaluated for any of the 10 communities. The better quality water is usually used only for drinking, cooking, and washing, and the poor-quality water for irrigation and disposal of wastes.

Dual water systems are being considered by the Department of Parks and Recreation in the development plans for Refugio State Beach and Gaviota State Park. The other communities did not consider a dual system to be feasible, due to the cost of adding another water main to an existing distribution system and the additional service connections and plumbing required for each service.

The City of Coalinga in western Fresno County is an example of a California community where a dual water system was used , because the poor quality of the local water supply created a problem. First, a better quality water supply was imported by railroad to provide water for drinking and cooking. Later the desalting of the poor-quality local water supply eliminated the importing of water by railroad. Recently the desalting plant was shut down when an ample supply for good quality water was imported by canal, thereby eliminating the need for two separate water systems.

Energy Requirements

Each desalting process requires the use of energy. The amount of energy used varies with the desalting process; however, all water treatment processes require the use of some energy. For each desalting process the fluids are moved through the system by pumps. In most small systems, the pumps are driven by electric motors. In larger systems, the pumps may also be operated by gas or steam turbines or by gas or diesel reciprocating engines.

In addition to just moving fluids, high pressures must be developed by pumps in the reverse osmosis process. In the electrodialysis process, additional energy is used to develop a direct-current electrical field in the fluid to be desalted. In the distillation or evaporation process, heat to cause a change from liquid to water vapor is provided by burning fuel or by compression of a fluid.

Concern about the future cost and availability of energy is important in the planning of future water treatment facilities. For the assessment studies discussed in this report, the electrical energy requirements and demands are shown in Table A-5 in Appendix A.

Impact on the Environment

Consideration of all external conditions and influences that affect life and its development is important in evaluating the impact of a desalting application on the environment. The principal factors to be considered are visual conditions, noise, and the effects of construction and operation on the human environment and wildlife habitat.

Buildings to house facilities can be made attractive by design, painting, and screens of natural growth. If the facilities are not housed, they can be made attractive in a like manner. If noise is a problem, the housing can be designed to minimize the noise. In the assessment studies, the disposal of brines is by evaporation in open-lined basins or by discharge into saline water. Impermeable linings would control the lateral and vertical movement of water from the basin. The location of the basins and natural plantings around them could provide some recreation and wildlife cover. Discharges into sea water will require careful planning and construction to minimize disturbance of wildlife habitat and to meet discharge requirements.

In all desalting applications, some storage of treated water will be necessary; however, the same amount of storage will be required for water supplies from other sources. All pipe lines outside the perimeter of the desalting plant would be buried and thus out of sight.

Boron

Summary of Assessment for Boron

	Quantity, mgd	*Quality, ppm of TDS*	*Desalting Cost, $ per 1,000 gals.*
Desalted Water	0.64	150	1.09
Raw (untreated) Water Used For Blending	0.36	1,030	
Total Blended Product	1.00	470	0.70
Capacity of Desalting Plant	0.64 mgd		
Annual Desalting Plant Load Factor	45 percent		

Data is for the lowest cost method of achieving the criteria desired by Boron. Schematic drawing of the physical arrangements is shown in Figure 15, and data on alternative methods are shown in Table 2 and in Appendix A.

Boron is an isolated residential-commercial community in the southeastern corner of Kern County on the high plains of the Mojave Desert at an elevation of about 2,500 feet (Figure 2). The population is about 2,500. The principal local industry is borax mining; a large open-pit mine nearby, operated by the U. S. Borax Company, produces a large part of the free world's Borax supply. The U. S. Air Force Flight Test Center at Edwards Air Force Base, which also employs a large number of workers, is located just south of Boron. The land surrounding Boron is not used for agriculture.

State Highway 58 formerly passed through Boron and intersected U. S. Highway 395 about 7 miles east of town. However, the highway was recently relocated to bypass the community, and the decreased traffic has resulted in some economic hardship. A main line of the Atchison, Topeka & Santa Fe Railroad also runs through Boron; a branch line serves the local borax industry.

Temperature extremes in the area range from a low of 5°F in the winter to about 100°F during the summer. Annual long-term precipitation has varied from 0.8 inches to 9.5 inches.

Water Supply

Boron is supplied with ground water from the North Muroc Subunit of the Antelope Valley-East Kern Water Agency (AVEK). The water is obtained from two wells about 6 miles from town. The water surface is about 160 feet below ground; each well delivers about 800 gallons per minute. Combined monthly water production in 1971 varied from 4.1 million to 28.1 million gallons. The water system serves 725 residential and commercial connections.

The community is dependent on ground water because no surface water is available for development. The nearest water import facility is the State Water Project; the closest project canal is 35 miles away. Although AVEK has an entitlement to State Water Project water, during a recent bond election to finance conveyance facilities, the required two thirds majority approval of the issue was not obtained (although a simple majority voted in favor of the measure). More recently the State Legislature approved a new law, under which such bond issues may be approved by a simple majority. In June 1974, voters approved a bond issue to finance the water distribution facilities. AVEK estimates that State Water Project water will be available in about two years at a cost (to AVEK) of at least $74 per acre-foot.

Boron has a community water system but no waste water disposal system. However, a disposal system and treatment plant have been planned. The community proposes to finance this system through a bond issue and a federal grant.

The Salt Problem

A preliminary water quality survey of the AVEK area, which includes Boron and other communities in the Antelope and Fremont Valleys, indicates that the ground water is a calcium, sodium, bicarbonate, sulfate type with a TDS of 120 to 2,100 ppm. In many parts of the area, the ground water contains high concentrations of nitrate, chloride, boron, and arsenic.

The salt problem in the Boron water supply is caused by a high TDS content, which exceeds the levels recommended by the U. S. Public Health Service and the California Department of Health. The high chloride content causes severe corrosion; the excessive fluorides can be injurious to teeth and bones. Hardness and boron also exceed desirable levels but are not mentioned in recommendations by these agencies. Other small communities near Boron have similar water supply problems.

Water quality analyses for water from each of the two wells that supply Boron are shown in Table 1. For well No. 13, the TDS of 1,175 ppm, chlorides of 434 ppm, and hardness as calcium carbonate ($CaCO_3$) of 288 ppm are higher than recommended. For well No. 15, the TDS of 892 ppm, fluorides of 0.94 ppm, and hardness as $CaCO_3$ also exceed recom-

mended levels. In addition, the boron concentration of 1.26 ppm in water from well No. 15 is higher than desirable for plants sensitive to boron. When the outputs of both wells are mixed, the delivered water has a TDS of about 1030 ppm, including fluoride of 1.0 ppm and a high sodium-chloride content.

Table 1. Chemical Composition of Water Supply in Boron

Constituent	ppm Well #13	ppm Well #15	ppm Average
Bicarbonate, HCO_3	179	185	182
Carbonates, CO_3	0	0	0
Chloride, Cl	434	241	338
Fluorides, F	0.7	0.9	0.8
Nitrate, NO_3	4	3	4
Nitrites, NO_2	0	0	0
Phosphate, PO_4	–	–	–
Sulfate, SO_4	221	233	227
Sulfides, S	0	0	0
Arsenic, As	0.05	0.06	0.06
Boron, B	–	–	–
Calcium, Ca	85	45	65
Copper, Cu	–	–	–
Iron, Fe	0.1	0.1	0.1
Magnesium, Mg	19	11	15
Manganese, Mn	0	0	–
Potassium, K	8	6	7
Selenium, Se	–	–	–
Sodium, Na	324	267	296
Hardness as $CaCO_3$	288	156	222
Total Dissolved Solids	1,175	892	1,034
pH	7.7	7.8	7.8
Conductivity (micromhos per cm)	1,740	1,230	1,490

– Not analyzed.

The salt problem affects the community in several ways. For example, most families in Boron use bottled water for drinking and cooking, and many are using water softeners. The chloride content of the water has corroded distribution pipes and plumbing fixtures. Ornamental plants are almost impossible to grow, probably because of the chlorides and boron in the water. The community has considered upgrading its water supply by installing individual water-tap desalting units with disposable elements.

The citizens of Boron are definitely interested in improving the quality of their water supplies. A similar interest may prevail in other nearby communities.

Desalting Application

Desalting facilities could be provided in line with existing water supply facilities as shown in Figure 14. The two wells that supply Boron are connected by a common pipeline to a booster pump; from the pump, the water moves through a pipeline to a 1-million-gallon storage tank about 4 miles away. The desalting plant could be located between the wells and the booster pump.

Figure 14 shows the location of existing water facilities and the possible location of the desalting facilities. Figure 15 is a block diagram showing how the desalting facilities could be incorporated into the existing water system.

Evaporation was assumed to be the most practical method for disposal of brines. The evaporation basin would be constructed so that brine could not move downward or laterally from the basin. The estimated net annual evaporation rate at Boron is 100 inches per year. A basin with a water surface area of 4.7 acres would be required for disposal of the brine produced annually by reverse osmosis.

The desalting facilities would have a minimum adverse impact on the environment. All facilities would be located about 3.5 miles from the nearest buildings in Boron. The desalting plant would be housed in a small, one-story building, about the size of a residen-

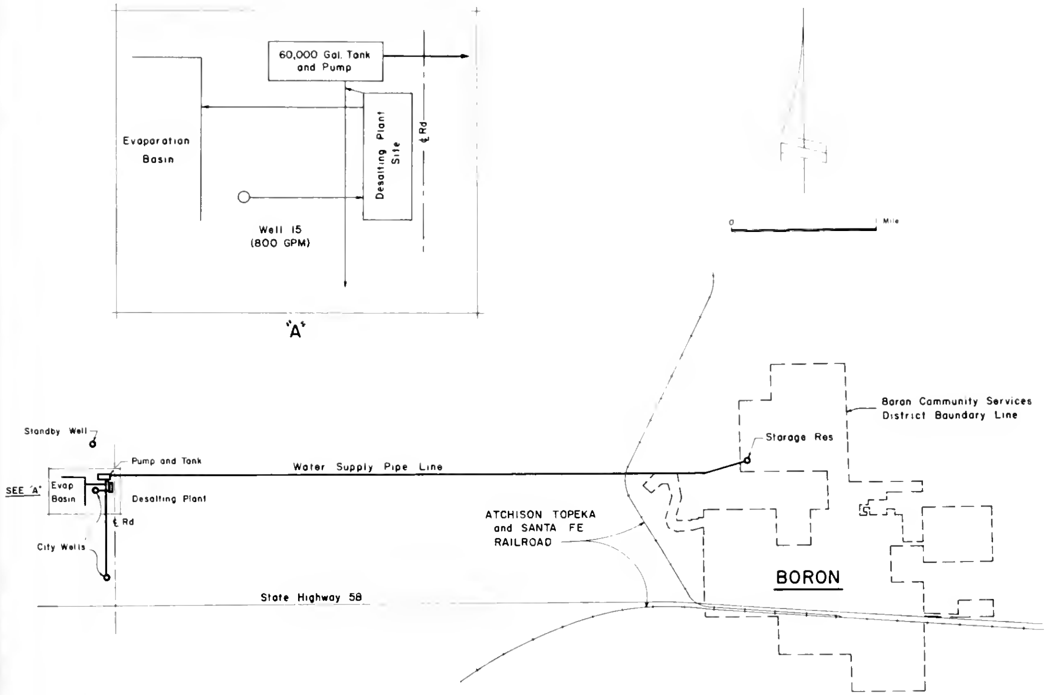


Figure 14. Location of Proposed Desalting Facilities in Boron

tial garage, near the existing 60,000-gallon storage tank. The evaporation basin would have a low profile and would be noticeable only within a short distance of the site. There should be no odor from the basin. Noise generated by pumps could be suppressed.

Benefits

The residents of Boron would benefit from improved water supplies through (1) increased life of appliances and galvanized iron pipe in plumbing systems, (2) decreased use of water softeners and bottled water, and (3) reduced need for soaps and washing powders.

Home water heaters with a 5-year guarantee usually last about 5 years when used with unsoftened water; with soft water, water heaters will last about 7 years. Evaporative air coolers and refrigerator icemakers require less frequent repair when soft water is used.

Water softeners are used in about 25 percent of the homes in Boron. In addition to the cost of the softener, there is the additional cost of frequent recharging. However, those who use water softeners require only about half as much soap and detergent than do those who use unsoftened water.

Boron does not have a municipal sewage disposal system, and the community is served by individual septic tanks. This causes another problem for homeowners; because of the excessive washing powders and soaps used, if waste water from a washing machine is discharged into a septic tank, the tank will not function properly. As a result most families must use a local laundromat.

Bottled water is delivered to 325 customers in Boron at $1.97 for 5 gallons. The monthly consumption of bottled water ranges from 15 to 20 gallons per person during the summer; during the winter, only about half this amount is used.

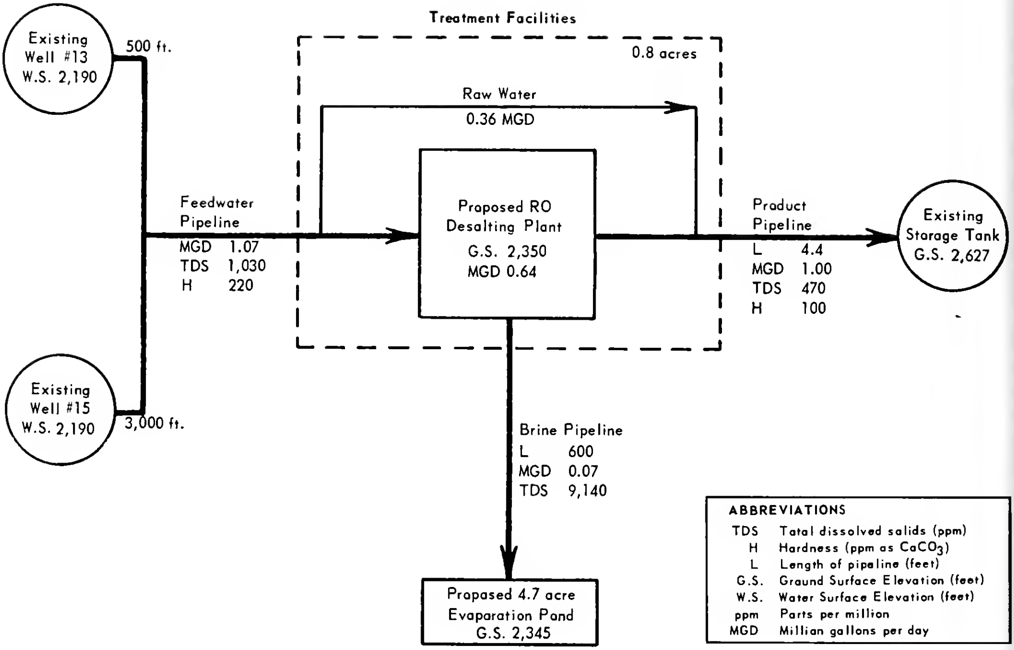


Figure 15. Schematic Diagram of Proposed Desalting Operation in Boron

Feasibility

In the analysis of desalting applications for Boron, ion exchange, electrodialysis, and reverse osmosis were evaluated. The results are summarized in Table 2. Because the concentration of salts in the feedwater is relatively low, distillation was not considered practical and was not evaluated. The TDS concentration can be reduced by any of the processes; however, some constituents, such as boron or fluorides, may not be reduced in the same proportion as is the TDS. As shown in Table 2, either reverse osmosis or electrodialysis would be the most feasible method of desalting in Boron.

Table 2. Boron: Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 165,000,000 gallons
Peak daily requirements .... 1,000,000 gallons
Annual desalting plant load factor .... 45 percent

Output	Process				
	Reverse Osmosis		Electrodialysis		Ion Exchange
	1/	2/	1/	2/	
Annual output (millions of gallons)					
Desalted	99	106	165	165	99
Raw	66	59	0	0	66
Total blended product	165	165	165	165	165
Peak daily output (millions of gallons)					
Desalted	0.60	0.64	1.00	1.00	0.60
Raw	0.40	0.36	0	0	0.40
Total blended product	1.00	1.00	1.00	1.00	1.00
Characteristics of blended product					
TDS (ppm)	500	466	500	466	500
hardness (ppm as $CaCO_3$)	107	100	107	100	100
Costs					
Capital costs ($1,000s)	609	652	830	830	964
Annual costs ($1,000s)					
Capital	41.8	44.7	56.9	56.9	65.9
Operations and maintenance	58.0	60.5	63.2	63.2	57.4
Replacement	9.9	10.6	9.5	9.5	12.2
Total	109.7	115.8	129.6	129.6	135.5
Cost of blended product per 1,000 gallons ($s)					
Capital	0.25	0.27	0.35	0.35	0.40
Operations and maintenance	0.35	0.37	0.38	0.38	0.35
Replacement	0.06	0.06	0.06	0.06	0.07
Total	0.66	0.70	0.79	0.79	0.82
Land requirement (acres)	5.7	6.2	11.6	11.6	40.2

[1] For degree of treatment required to reduce TDS to 500 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 100 ppm.

Buellton

Summary of Assessment for Buellton

	Quantity, mgd	*Quality, ppm of TDS*	*Cost of Treatment * $ per 1,000 gals.*
Treated Water *	0.39	440	1.14
Raw (untreated) Water Used For Blending	0.08	790	
Total Blended Product	0.47	500	0.95

Capacity of Desalting Plant .... 0.23 mgd
Annual Desalting Plant Load Factor .... 64 percent

* 0.23 mgd is desalted; 0.16 mgd is softened
Data is for the lowest cost method of achieving the criteria desired by Buellton. Schematic drawing of the physical arrangements is shown in Figure 17, and data on alternative methods are shown in Table 4 and in Appendix A.

Buellton is an isolated residential-commercial community in the Santa Ynez Valley of Santa Barbara County, about 25 miles inland from the Pacific Ocean (Figure 2). The community is located on U. S. Highway 101, a main transportation route near the coast, about midway between Santa Maria and Santa Barbara.

The permanent population of Buellton is about 1,600. However, the Santa Barbara County Planning Department has predicted that Buellton's population will at least double between 1970 and 2000. These predicted increases are based on anticipated population shifts from densely populated areas to less populated areas, such as Buellton, and by recent restrictions on coastal development, which may cause developers to shift their operations to inland areas.

Buellton serves travelers with several motels, a popular restaurant, and a large recreational-vehicle complex. Other local commercial and industrial activities include a number of petroleum wells located between Buellton and Santa Maria, and the Vandenberg Air Force Base Missile Test Center about 25 miles from Buellton on the Pacific Coast.

The community is surrounded by rolling grass-covered hills used for cattle grazing and by gently sloping croplands near the Santa Ynez River. Flow in the Santa Ynez River is impounded by Cachuma Dam about 15 miles upstream of Buellton. However, at the present time, because of existing allocations, releases from Cachuma Reservoir are used to maintain adequate streamflow, and the community is dependent on local ground water.

Temperature extremes range from about 23°F in the winter to near 100°F during the summer. Long-term annual precipitation records vary from 6.4 inches to 25.3 inches.

Water Supply

The Buellton Community Services District delivers water to 420 connections. The community obtains all of its water from two wells located on the opposite sides of town. One well (well No. 5) furnishes Buellton's primary municipal water supply. The other well (well No. 3) contains high concentrations of TDS, manganese and iron, and hardness ions, and is used as a standby to provide for peak flows and fire fighting. The domestic water supply is also used for landscape irrigation along U. S. 101 Freeway near Buellton.

Although the total concentration of salts in the water from well No. 5 is not as high as that in water from well No. 3, the water is still very hard, contains marginal amounts of manganese, and has caused significant problems. A water quality analysis of a sample from well No. 5 is shown in Table 3. The engineering consultant for the Community Services District has recommended that the District drill a new well at a new location.

The present water system includes two reservoirs, with capacities of 100,000 gallons and 300,000 gallons, respectively, on a bluff overlooking the community. Water is pumped directly into the community distribution system, and excess flows are stored in the reservoirs. Existing and proposed supply facilities for the water system, and the existing waste water treatment plant, are shown in Figure 16.

The Salt Problem

The principal salt problems in Buellton's water supplies are discoloration, caused by excessive manganese and iron, and excessive hardness. The concentrations of iron, manganese, and hardness ions in water from well No. 3 are several times the recommended maximum. Concentrations of TDS and manganese in the water from well No. 5 exceed those recommended for drinking water by the U. S. Public Health Service, but the problem is being mitigated by the Calgon process. The community water supplies have an unpleasant taste and odor, and most residents use bottled water for drinking and cooking.

Table 3. Chemical Composition of Water Supply in Buellton (Well No. 5)

Constituent	*ppm*
Bicarbonate, HCO_3	399
Carbonates, CO_3	–
Chloride, Cl	53
Fluorides, F	0.5
Nitrate, NO_3	<0.01
Nitrites, NO_2	–
Phosphate, PO_4	–
Sulfate, SO_4	265
Sulfides, S	–
Arsenic, As	–
Boron, B	–
Calcium, Ca	124
Copper, Cu	–
Iron, Fe	0.2
Magnesium, Mg	61
Manganese, Mn	0.06
Potassium, K	2
Selenium, Se	–
Sodium, Na	57
Silica, SiO_2	32
Hardness as $CaCO_3$	563
Total Dissolved Solids	791
pH	7.3
Conductivity (micromhos per cm)	970

– Not analyzed.

Because the water supply is excessively hard, many residents use home water softeners, some of which are exchange units and others the regenerative type. The use of the regenerative softeners has resulted in the disposal of brine into the waste water disposal system, which, in turn, produces a high concentration of salts in the wastes discharged from the system.

As a result, the California Regional Water Quality Control Board, Central Coast Region, has set new limits for the concentration of TDS, chlorides, sulfates, and sodium in the wastes discharged. At times, the salt content of the waste water discharged has been several times higher than the prescribed limits. To help meet the requirements of the Control Board order, in 1973 the community adopted an ordinance that (1) prohibits the installation of regenerative-type water softeners, and (2) prescribes that the use of those already installed be discontinued by 1978.

One solution to the salt problem would be to desalt the waste water to an acceptable level before discharge. However, this would not improve the quality of the original water supply. The community would realize the greatest benefit if the incoming water were treated, with the intent of eliminating, or at least reducing, the use of residential water softeners. This treatment could also be used to solve the discoloration problem.

The discoloration is attributed to excessive manganese and iron in the water supply. After the water stands for awhile, a black precipitate, which causes staining, is formed. The condition is particularly noticeable in toilet bowls and tanks and when faucets are first turned on. After the water has run for a short time, the flow becomes clear. Many of the wells in the Buellton area produce water in which this black precipitate forms, and the Community Services District receives frequent complaints about it from its customers.

Another type of precipitate, which when dry is dark brown and easily crumbles, has formed on the floor of the community storage reservoir. An analysis of this material indicates that it is calcium carbonate plus some metal impurities. The deposit is probably caused by chemical action of the very hard water.

Many of the residents of Buellton have learned to live with the water problem. However, the community's concern with improvement of the quality of the water supply is reflected by the increasing use of residential water softeners. Moreover, the order of the California Regional Water Quality Control Board has emphasized that waste water quality must be improved soon.

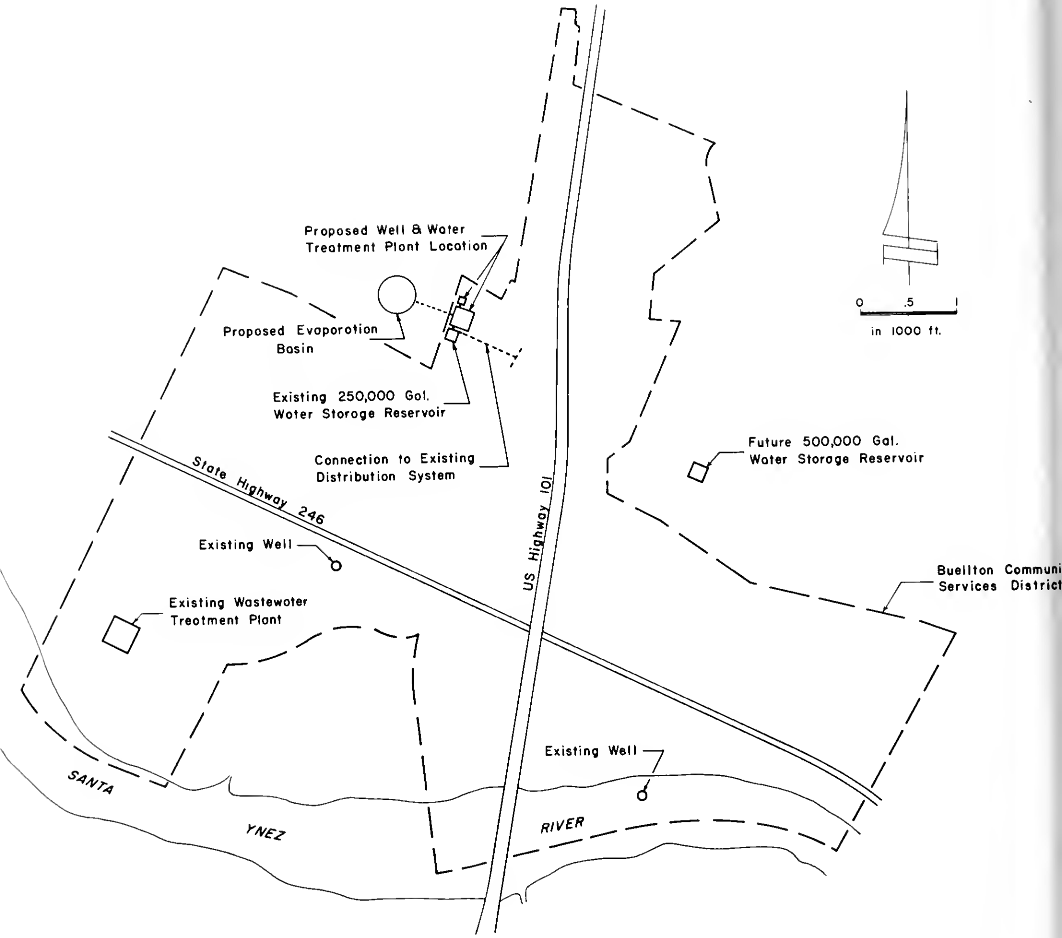


Figure 16. Location of Proposed Desalting Facilities at Buellton

Desalting Application

A new well could be drilled adjacent to the existing storage reservoir on a bluff northwest of the community, and desalting facilities could be constructed between the well and the reservoir. Although the quality of the water from the new well will not be determined before construction, it presumably will be as good as that of the water from well No. 5, the principal source of Buellton's present supply. Evaporation basins for disposal of brines could be located on a flat bluff slightly higher than the proposed site for the desalting plant.

For specific water treatment, e.g., softening or removing certain ions that cause discoloration, other processes, such as coagulation, filtration, sedimentation, and oxidation, might be less costly than desalting. However, these processes will not reduce TDS to the levels recommended for municipal water supplies. Moreover, the addition of coagulants, such as lime-soda or aluminum sulfate, will produce sludges or other residues requiring disposal.

Figure 16 shows the location of existing water-supply facilities and suggested sites for the proposed desalting facilities. Figure 17 is a block diagram of the proposed desalting facilities and water system, including a new well at the site recommended to the Community Services District.

The most practical method of brine disposal would be evaporation. The brines would be discharged in a basin on a plateau above the community. The basin would be constructed so that no residue could move downward or laterally from the site. The estimated net annual evaporation rate is 38 inches per year. Disposal of the brines produced by ion exchange would require a basin with a water surface of 31 acres.

At the proposed site, the desalting plant would have minimum adverse impact on the environment; however, the effect of the evaporation basin would depend on the development that might take place nearby. The desalting plant could be housed in a small, one-story building, about the size of a residential garage, near the existing reservoir. At the higher elevation proposed for the evaporation basin, it would not be visible from the community.

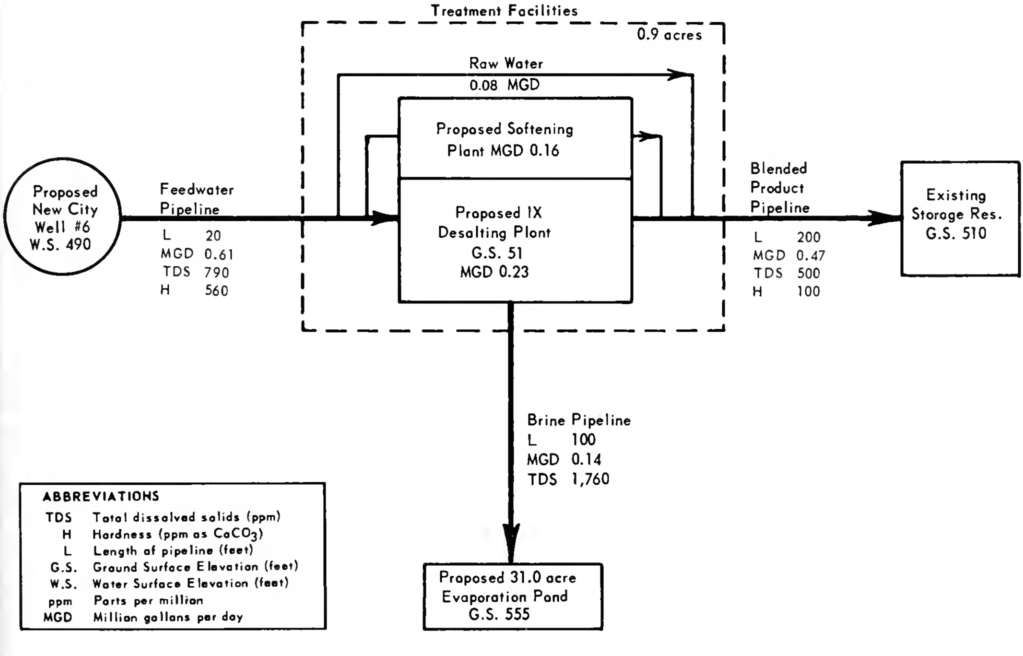


Figure 17. Schematic Diagram of Proposed Desalting Operation in Buellton

Benefits

Providing a good-quality water supply would be a benefit to all citizens of Buellton. Desalting to reduce both TDS and hardness and to remove iron and manganese could eliminate the need for bottled water and water softeners, reduce the consumption of washing powders and soaps, and extend the service life of water heaters and the galvanized iron pipe used in home and commercial plumbing systems.

Those who use regenerative water softeners must pay both the cost of the appliance plus the cost of frequent regeneration. And, as explained in the previous paragraphs, a new city ordinance prohibits the use of regenerative units after 1978. Although the ordinance will not prevent the use of exchange-type softeners, the present cost of an exchange unit is about $13 per month. As an example of the benefits that would result from a reduction in hardness, those who use water softeners realize a 40- to 50-percent savings in the cost of washing powders and cleaning materials.

The weekly consumption of bottled water in Buellton varies throughout the year from 2 to 4 gallons per person. The delivered cost of 5 gallons of bottled water is $2.

In Buellton, if softened water is used, water heaters with a guaranteed life of 5 years generally last for about 6 years. If water is not softened, heaters must usually be replaced after 3 years. The hard water is also responsible for heavy deposits of scale in the galvanized iron pipe used in home and commercial plumbing systems, which results in reduced flows and lower pressure. (City water mains and service connections are transite and copper, respectively, and are not subject to scaling.)

Feasibility

The engineering consultant for Buellton has recommended that the Community Services District construct a new well to furnish municipal water supplies. The well has not been constructed; however, the quality of water from the new well will probably be similar to that of the water from well No. 5, which now furnishes Buellton's principal water supply. In the present water supplies, concentrations of TDS and manganese exceed the USPHS recommended limits the concentration of iron is near the recommended limit, and the water is very hard.

Reverse osmosis, electrodialysis, and ion exchange were evaluated as possible desalting processes in Buellton. The results of the analysis are presented in Table 4. Although any of the three could be used, the engineering consultant has evaluated and recommended lime-soda precipitation, a well-known softening process. He has predicted that the lime-soda process would reduce (1) the hardness to 100 ppm, and (2) TDS by about 260 ppm, i.e., from 790 ppm to 530 ppm, close to the recommended level of 500 ppm. A disadvantage of lime-soda precipitation is that the large amount of chemicals added to the water produce large quantities of sludge, which must be converted to a semi-solid state and trucked to a suitable disposal site.

The engineering consultant has estimated the construction cost of a 500,000-gpd lime-soda softening plant at $226,000 (1973 base). He has also estimated an annual cost of $52,600 including operation and maintenance, and amortization of capital costs over 25 years. The estimated unit cost of softened water is about $0.48 per 1,000 gallons.

Because the unit cost of the lime-soda is lower than that of any of the three processes shown in Table 4, it appears to be the most feasible method for desalting at Buellton. Manganese and iron concentrations could also be removed by oxidation and filtration at a relatively low cost. Although the other three processes would reduce TDS to less than 530 ppm, the difference would have a negligible value to consumers. Distillation is not a feasible process for desalting water of the TDS concentration at Buellton.

Table 4. Buellton: Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 110,000,000 gallons
Peak daily requirements .... 470,000 gallons
Annual desalting plant load factor .... 64 percent

Output	Process				
	Reverse Osmosis		Electrodialysis		Ion Exchange
	1/	2/	1/	2/	
Annual output (millions of gallons)					
Desalted	49	110	110	110	55
Softened	0	0	0	0	37
Raw	61	0	0	0	18
Total blended product	110	110	110	110	110
Peak daily output (millions of gallons)					
Desalted	0.21	0.47	0.47	0.47	0.235
Softened	0	0	0	0	0.155
Raw	0.26	0	0	0	0.08
Total blended product	0.47	0.47	0.47	0.47	0.47
Characteristics of blended product					
TDS (ppm)	500	140	500	140	500
hardness (ppm as $CaCO_3$)	356	100	356	100	100
Costs					
Capital costs ($1,000s)	356	691	781	1,005	849
Annual costs ($1,000s)					
Capital	23.9	46.3	52.4	67.8	55.7
Operations and maintenance	29.3	48.1	39.3	41.3	42.7
Replacement	4.9	11.0	4.8	11.0	6.3
Total	58.1	105.4	96.5	120.1	104.7
Cost of blended product per 1,000 gallons ($s)					
Capital	0.22	0.42	0.48	0.62	0.50
Operations and maintenance	0.27	0.44	0.36	0.39	0.39
Replacement	0.04	0.10	0.04	0.10	0.06
Total	0.53	0.96	0.88	1.09	0.95
Land requirement (acres)	7.4	16.3	18.1	18.1	36.6

[1] For degree of treatment required to reduce TDS to 500 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 100 ppm.

Greenfield

Summary of Assessment for Greenfield

	Quantity, mgd	Quality, ppm of TDS	Cost of Treatment * $ per 1,000 gals.
Treated Water *	0.32	446	0.92
Raw (untreated) Water Used For Blending	0.08	720	
Total Blended Product	0.40	500	0.74

Capacity of Desalting Plant .... 0.16 mgd
Annual Desalting Plant Load Factor .... 75 percent
* 0.16 mgd is desalted; 0.16 mgd is softened

Data is for the lowest cost method of achieving the criteria desired by Greenfield. Schematic drawing of the physical arrangements is shown in Figure 19, and data on alternative methods are shown in Table 7 and in Appendix A.

Greenfield, an agricultural center in the northern Salinas Valley, is situated on U.S. Highway 101 Monterey County (Figure 2). The 1970 population was about 3,000. In 1972, the municipal water supply system delivered water to about 550 connections. Greenfield is also served by a municipal waste water disposal system.

The Salinas Valley extends for about 130 miles in Central California between two mountain ranges that roughly parallel the coastline; the Valley meets the ocean at Monterey Bay. The number and variety of vegetables shipped from the Salinas Valley have made it famous as the "Salad Bowl of the Nation". Near Greenfield, the irrigated portion of the Valley is about 7 miles wide.

Temperature extremes range from about 15°F in the winter to about 110°F in the summer. Long-term annual precipitation records vary from 3.1 inches to 19.0 inches.

Water Supply

Greenfield's water supply is ground water from two wells, each capable of producing up to 1,100 gallons per minute. The water is pumped from about 140 feet below ground. Water from the well that furnishes the main source of municipal supply (well No. 6) has a TDS concentration of 718 ppm (Table 5). The second well (well No. 2) produces water with a TDS concentration of 1,400 ppm and is used as a standby; well No. 6 furnishes 99 percent of Greenfield's domestic and commercial water supply. An elevated 100,000-gallon storage reservoir at the site of well No. 6 is connected through the distribution system to well No. 2.

The Salinas River channel, located just outside and east of Greenfield, conveys water from upstream reservoirs to recharge the underlying ground water basin as far north as the vicinity of Chualar. Percolation from the river is one of the main sources of ground water replenishment in the Salinas River Basin. The ground water basin in the vicinity of Greenfield is also replenished by the west side tributaries to the valley. Ground water from these sources has a TDS concentration of about 200 to 300 ppm, whereas the TDS concentration of ground water from the east side of the valley is higher.

The Salt Problem

A water quality analysis of a sample from well No.

Table 5. Chemical Composition of Water Supply in Greenfield *

Constituent	ppm
Bicarbonate, HCO_3	278
Carbonates, CO_3	–
Chloride, Cl	85
Fluorides, F	0.32
Nitrate, NO_3	5
Nitrites, NO_2	–
Phosphate, PO_4	–
Sulfate, SO_4	234
Sulfides, S	–
Arsenic, As	<0.003
Boron, B	–
Calcium, Ca	116
Copper, Cu	–
Iron, Fe	0.2
Magnesium, Mg	–
Manganese, Mn	<0.02
Potassium, K	5
Selenium, Se	–
Sodium, Na	59
Hardness as $CaCO_3$	490
Total Dissolved Solids	718
pH	7.6
Conductivity (micromhos per cm)	1,070

– Not analyzed.
* From Well No. 6.

6 shows that Greenfield's water supplies are excessively hard and that TDS concentrations are above recommended levels for municipal supplies. As a result of the hardness, regenerative water softeners are used within the city and cause a high salt content in the waste water. This results in the principal salinity problem of the city: the salt content of the effluent from the waste water treatment plant, which discharges into oxidation-percolation basins near the Salinas River, exceeds the permissible level. The highly saline waste water eventually percolates into the underlying ground water basin, raising the TDS concentration of the ground water down slope from the city's supply wells.

The community has been operating the treatment plant under 1969 waste discharge requirements issued by the California Regional Water Quality Control Board, Central Coast Region. In February 1973, the Control Board established lower limits for the concentration of salts in waste discharges from the treatment plant. The new requirements, which will become effective July 1, 1975, are presented in Table 6.

Table 6. MINERAL CONTENT OF PRESENT DISCHARGE FROM GREENFIELD WASTE WATER TREATMENT PLANT COMPARED WITH THAT PERMITTED BY NEW WASTE DISCHARGE REQUIREMENTS
(parts per million)

Constituent	*Concentration in water supply*	*Permissible increases **	*Permissible concentrations in waste water established by new discharge requirements*		*Existing concentration in discharge from treatment plant*	*Excess salts in present discharge above permissible median concentration*
			Median	*Maximum*		
	(1)	*(2)*	*(3) = (1) + (2)*		*(4)*	*(5) = (4) − (3)*
TDS	718	400	1,118	1,200	1,321	203
Sodium	59	150	209	250	241	32
Chloride	85	150	235	250	301	66
Sulfate	234	75	309	400	310	1

* = Salts discharged into waste water as it passes through city waste disposal system

One solution to the salinity problem would be desalination of the waste water. However, this approach would not reduce the hardness or TDS levels of the community's water supplies, and the use of home water softeners would probably continue. On the other hand, if the community water supplies were desalted, TDS concentrations and hardness as $CaCO_3$ could be reduced to acceptable levels. Community representatives have requested consideration of reductions of TDS from 718 ppm to 500 ppm, and of hardness from 490 ppm, to 100 ppm. These criteria would enable waste discharges with a TDS concentration well within the new limits prescribed by the Regional Water Quality Control Board.

Desalting Application

The proposed desalting plant could be located at the site of well No. 6 and the adjoining storage reservoir. Although these facilities are in a residential area, the site would permit the shortest connection between the well, the desalter, and the reservoir. Existing water supply facilities and the proposed desalting facilities are shown in Figure 18. The block diagram in Figure 19 shows how the desalting facilities would fit into the existing water supply system.

Evaporation has been suggested as the most practical method of brine disposal. The community has requested that the brine evaporation basins be located about 2 miles northeast of the community near the waste water treatment plant. The proposed site is on city-owned land near the Salinas River, and the basins would have to be protected from floodflows. The brines would be discharged from the desalter to the evaporation basins through a pipeline about 3 miles long.

The estimated net evaporation rate is 42 inches per year. At this rate, 21 acres of water surface would be required for the disposal of brines produced by ion exchange.

Although the proposed desalting plant would be in a residential area, the residential pattern has already been broken by the existing pump and the storage reservoir. Of course, the desalter would have to be housed in a manner that would be acceptable to the community.

Construction of the brine pipeline would require an open ditch through the city streets between the desalter and the evaporation basins. However, the ditch could be filled as quickly as each segment of the pipe is installed, and the unfavorable impact would

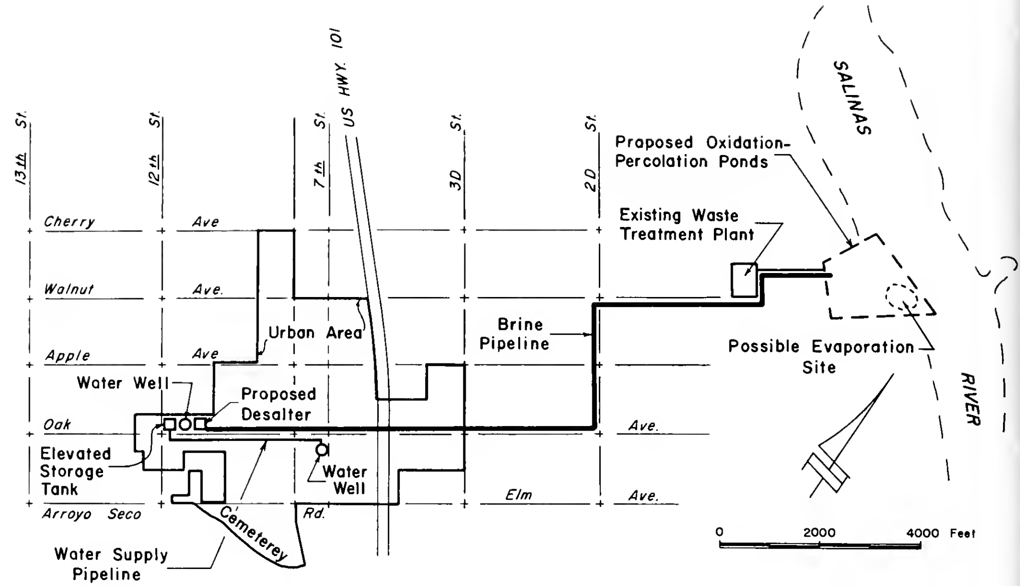


Figure 18. Location of Proposed Desalting Facilities at Greenfield

be only temporary. The appearance of the evaporation basin located near the treatment plant would be similar to that of the oxidation-percolation basins proposed for disposal of other waste water, and should result in only minor unfavorable impact.

Benefits

Almost all households and commercial establishments in Greenfield would benefit from the improved quality of the city's water supplies. The principal improvement would be a reduction in hardness. Benefits from a lower TDS concentration would not be as significant, because the present TDS level of about 718 ppm is close to the recommended level of 500 ppm. On the other hand, softer water supplies, should eliminate, or at least greatly reduce, the use of home water softeners, which are believed to be the principal cause of degradation of the local ground water. As explained in previous paragraphs, brines from the regenerative softener units are discharged into the municipal waste water disposal system; the highly saline waste water effluents eventually percolate into the underlying ground water basin and raise the TDS concentration of the ground water.

The benefits of softer community water supplies would result from (1) the increased service life of water heaters, automatic washers, dishwashing machines, and ice-makers in refrigerators (2) the reduced need for washing powders, soaps, and other cleaning materials; (3) elimination of the need for water softeners; and (4) elimination of scale in water distribution systems.

When Greenfield's water is used without softening, problems such as the following are typical: Water heaters ordinarily guaranteed for 10 years are usually replaced in 4 to 6 years. Moreover, scale deposited by the excessively hard water can reduce the capacity of a typical water heater during the same period. Automatic clothes washers gradually accumulate a thick layer of alkali, which generally must be removed after about 6 years of operation, at a cost of about $80. Dishwashing machines frequently must have valves replaced about every 3 years at a cost of about $20. To operate effectively, ice-makers in refrigerators should be rebuilt after only 1 year

An important benefit would result if residential softeners were no longer needed. Many of the newer homes in Greenfield have been constructed with special facilities to accommodate a water softener.

Both regenerative and exchange-type softners are used at the present time. The average price of a home regenerative water softener is about $350; in Greenfield, the equipment is guaranteed for only 2 years. Some regenerative softeners must be recharged every few days and use up to 300 pounds of salt per month at $3.00 per 100 pounds. Exchange-type water softening units may be rented for about $12 per month.

Feasibility

The principal water supply problem in Greenfield is hardness, because the TDS concentration of 718 ppm is not far above the recommended level of 500 ppm. Therefore, a hardness-reduction treatment, instead of desalting, may be the most feasible process to both soften the water and reduce TDS. This conclusion is based on the estimated costs in Table 7 and the estimated cost of the lime-soda process as discussed in the preceding section (under Buellton).

The site for the required facilities will be a significant consideration in Greenfield. As explained in the preceding paragaphs, the main well and the storage tank are in a residential area, and therefore adequate space may be a problem. The treatment facilities required for lime-soda precipitation require considerably more space than do those required for reverse osmosis, electrodialysis, or ion exchange, provided that the brine disposal basins are located off site. Facilities for any of the preceding desalting processes could be housed in a building about the size of a residential garage. Lime-soda softening will also produce large quantities of sludge, which would probably have to be trucked to a disposal site.

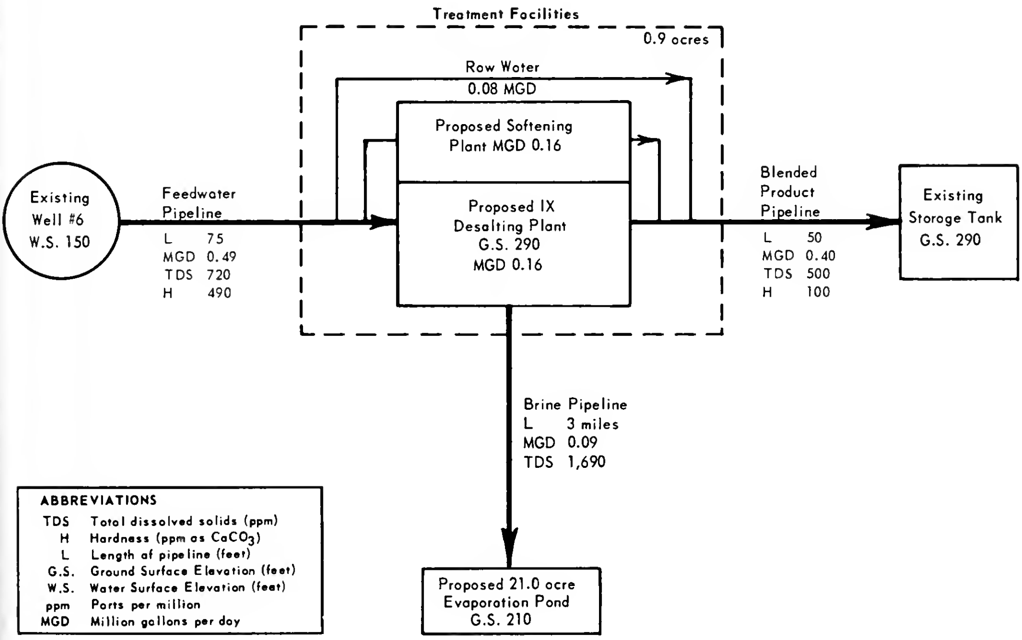


Figure 19. Schematic Diagram of Proposed Desalting Operation at Greenfield

Table 7. Greenfield: Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 109,500,000 gallons
Peak daily requirements .... 400,000 gallons
Annual desalting plant load factor .... 75 percent

Output	Process				
	Reverse Osmosis		Electrodialysis		Ion Exchange
	1/	2/	1/	2/	
Annual output (millions of gallons)					
Desalted	41.0	109.5	109.5	109.5	44.0
Softened	0	0	0	0	44.0
Raw	68.5	0	0	0	21.5
Total blended product	109.5	109.5	109.5	109.5	109.5
Peak daily output (millions of gallons)					
Desalted	0.15	0.40	0.40	0.40	0.16
Softened	0	0	0	0	0.16
Raw	0.25	0	0	0	0.08
Total blended product	0.40	0.40	0.40	0.40	0.40
Characteristics of blended product					
TDS (ppm)	500	147	500	147	500
hardness (ppm as $CaCO_3$)	341	100	341	100	100
Costs					
Capital costs ($1,000s)	253	553	607	791	514
Annual costs ($1,000s)					
Capital	17.3	37.9	41.6	54.3	35.2
Operations and maintenance	25.1	45.4	36.1	37.3	40.4
Replacement	4.1	11.0	3.2	9.5	5.4
Total	46.5	94.3	80.9	101.5	81.0
Cost of blended product per 1,000 gallons ($s)					
Capital	0.15	0.35	0.38	0.50	0.32
Operations and maintenance	0.23	0.41	0.33	0.34	0.37
Replacement	0.04	0.10	0.03	0.09	0.05
Total	0.42	0.86	0.74	0.93	0.74
Land requirement (acres)	6.7	16.0	17.0	17.0	25.1

[1] For degree of treatment required to reduce TDS to 500 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 100 ppm.

Old Cuyama

Summary of Assessment for Old Cuyama

	Quantity, mgd	*Quality, ppm of TDS*	*Desalting Cost, $ per 1,000 gals.*
Desalted Water	0.023	160	4.46
No blending feedwater	–	4,330	
Capacity of Desalting Plant	0.023 mgd		
Annual Desalting Plant Load Factor	47 percent		
Data is for the lowest cost method of achieving the criteria desired by Old Cuyama Schematic drawing of the physical arrangements is shown in Figure 20, and data on alternative methods are shown in Table 9 and in Appendix A			

Old Cuyama, a trading center for the Cuyama Valley, is located on State Highway 166 in the northeastern corner of Santa Barbara County (Figure 2). The population of the community is 53. Old Cuyama is one of two small communities in the Cuyama Valley, which is about 25 miles long and which varies in width from 2 to 6 miles. Developments in Old Cuyama consist of a few commercial buildings, several residences, and the elementary school for the Cuyama Valley (1973 enrollment, 224 pupils).

Old Cuyama, and New Cuyama (4 miles west), are the only communities along a 76-mile stretch of State Highway 166 between Santa Maria and Maricopa. Although relatively isolated in rugged, mountainous country, the communities can be easily reached from the east or south. Maricopa is just 22 miles northeast via Highway 166; 25 miles farther east, the same highway connects with Interstate 5 at a point 15 miles south of Bakersfield. State Highway 33, which enters the Cuyama Valley 8 miles east of Old Cuyama, provides easy access to the coast; via this route, Ventura is 50 miles south.

The Cuyama Valley has been used for agriculture since 1843, when it was part of a Mexican land grant. Livestock grazing and dry farming were the principal activities until about 1940, when local farmers began to use ground water for irrigation. However, it was not until 1953 that electric power became available for pumping irrigation water and for domestic use. Agriculture remained the principal activity in the valley until about 1950, when oil was discovered nearby.

During the past few years, local landowners have tried to promote more residential development in Old Cuyama, offering as inducements the mild climate, the clear, dry air, and the many sunny days each year. Parcels of land have been developed for residential use, and a trailer park has been constructed. However, the planned community expansion has not occurred, chiefly because of restrictions imposed by local authorities. In 1971, the Santa Barbara County Health Department recommended that (1) no development be permitted unless local water supplies are demineralized, and (2) prospective purchasers of property be warned that the water is unusable for domestic use without treatment.

The climate in the Cuyama Valley is semiarid. Temperature extremes vary from a low of about 7°F to a high of 110°F. Long-term annual precipitation has ranged from about 3.5 inches to 12.7 inches; in the mountains surrounding the valley, annual precipitation has ranged from about 24 to near 30 inches.

Water Supply

The Cuyama Mutual Water Company distributes water to only 15 connections for residential and commercial use and for fire protection. Because of the bitter taste of this water, bottled water is used for drinking and cooking. The elementary school obtains water from its own 750-foot-deep well. However, because the nitrate concentration in this water is about 100 ppm, bottled water is also used at the school for drinking and cooking. If the water company could supply water of better quality, the school would probably buy it.

The water company distributes water under a temporary permit from the California Department of Health. The Health Department provides this type of authorization only for water systems already in use, pending construction of treatment facilities or development of acceptable new sources of water. The water company is definitely interested in providing improved water supplies and has proposed that Old Cuyama and New Cuyama form a community services district to provide better water supplies.

The ground water distributed by the water company is pumped from a 300-foot-deep well, which has been in use since 1944. The water level in the well is about 220 feet below ground surface. Old Cuyama has no waste water disposal system.

Except for minor amounts obtained from nearby springs, all of the water used in the Cuyama Valley

is pumped from wells. No surface water is available from the Cuyama River, because, before the river enters the valley, its waters infiltrate the coarse-grained deposits of its channel. Therefore, except for occasional flood flows, the river is dry most of the year. This water comprises the principal inflow to the valley ground water basins.

Ground water quality varies throughout the Cuyama Valley. In the central portion, TDS concentrations range from 1,500 to 1,800 ppm. This water varies from hard to very hard and is predominantly calcium-magnesium sulfate; these three constituents comprise 75 to 85 percent of the TDS content.

The quality of ground water around the periphery of the valley also varies. In some springs and wells, TDS concentrations range from 700 to 900 ppm; in other areas, from 3,000 to over 6,00 ppm, with as high as 1,000 ppm of chlorides and 15 ppm of boron. [1] In some parts of the valley, the ground water contains very high concentrations of nitrates; nitrate concentrations exceeding 400 ppm have been found in water from shallow wells and, occasionally, from wells 300 to 650 feet deep.

The nearest source of surface water that could be imported to the Cuyama Valley is the California Aqueduct, about 20 miles away in the southwestern San Joaquin Valley, However, because of the high hills that separate the two valleys, to import State Water Project Water from the aqueduct would require a pumping lift of about 2,000 feet.

The Salt Problem

A quality analysis of a sample of the ground water distributed by the Cuyama Mutual Water Company is presented in Table 8. The analysis shows that the TDS concentration of 4,333 ppm, sulfates of 2,650 ppm, nitrates of 243 ppm, and hardness as $CaCO_3$ of 2,642 ppm greatly exceed desirable levels. Ground water quality varies in different parts of the valley because of (1) the sources that make up the ground water bodies, (2) the rocks and soils that the water contacts, (3) subsurface geological fault zones that act as barriers to ground water movement, and (4) various impurities, such as fertilizers, in water that percolates from the valley floor.

Table 8. Chemical Composition of Water Supply in Old Cuyama

Constituent	*ppm*
Bicarbonate, HCO_3	309
Carbonates, CO_3	0
Chloride, Cl	195
Fluorides, F	<0.01
Nitrate, NO_3	243
Nitrites, NO_2	<0.001
Phosphate, PO_4	–
Sulfate, SO_4	2,650
Sulfides, S	<0.1
Ammonium, NH_4	<0.03
Arsenic, As	<0.01
Boron, B	–
Calcium, Ca	640
Copper, Cu	–
Iron, Fe	0.1
Magnesium, Mg	250
Manganese, Mn	0.01
Potassium, K	10
Selenium, Se	–
Sodium, Na	320
Hardness as $CaCO_3$	2,642
Total Dissolved Solids	4,333
pH	7.3
Conductivity (micromhos per cm)	5,400

– Not analyzed.

[1] U. S. Department of Interior, Geological Survey open file Report, "Pumpage and Ground Water Storage Depletion in Cuyama Valley - 1947-66". 1970.

Old Cuyama is located over part of a cone of depression in the local ground water that underlies a large area of the Cuyama Valley. Recent studies by the U. S. Geological Survey indicate that the depression is caused by heavy pumping of ground water for irrigation. The studies also indicate that the degradation of ground water quality is probably caused in part by recycling of the ground water. The increase in TDS in the main ground water body is probably caused by (1) irrigation water which percolates through the valley fill, carrying salt from the crop root zone to the water table, and (2) subsurface movement of brackish ground water downgradient into the cone of depression.

The water company could try to find better quality water supplies by deepening its existing well, drilling new wells, importing water from another part of the valley, or treating the present water to lower the salt concentration. Although water from another part of the valley might be less saline, treatment could still be required to satisfy the requirements of the California Department of Health.

Because of the highly saline water distributed by the water company, all residents must use bottled water for drinking and cooking, and some use residential water softeners. A typical problem associated with the hard, brackish water supply is the short life of water heaters. A heater guaranteed for 10 years will last only 6 or 7 years in Old Cuyama. Moreover, because there is no local appliance dealer, the installation cost of a water heater almost equals the cost of the heater itself. Another problem is the corrosion of steel pipe. The average life of good-quality steel pipe in Old Cuyama is about 10 years, and some foreign pipe has lasted only 3 years.

A secondary problem is the restraint on community development. Recently, a number of prospective purchasers of local property have changed their minds after learning of the poor water supply. A trailer park has been developed in Old Cuyama but cannot be used as planned. Community leaders believe that, if the water supply were improved, they could attract new residents, who would contribute to an expanded local economy.

Desalting Application

Electrodialysis and reverse osmosis were considered as possible desalting processes for Old Cuyama. Figure 20 is a block diagram which shows how the desalting facility could be fitted into the existing wa-

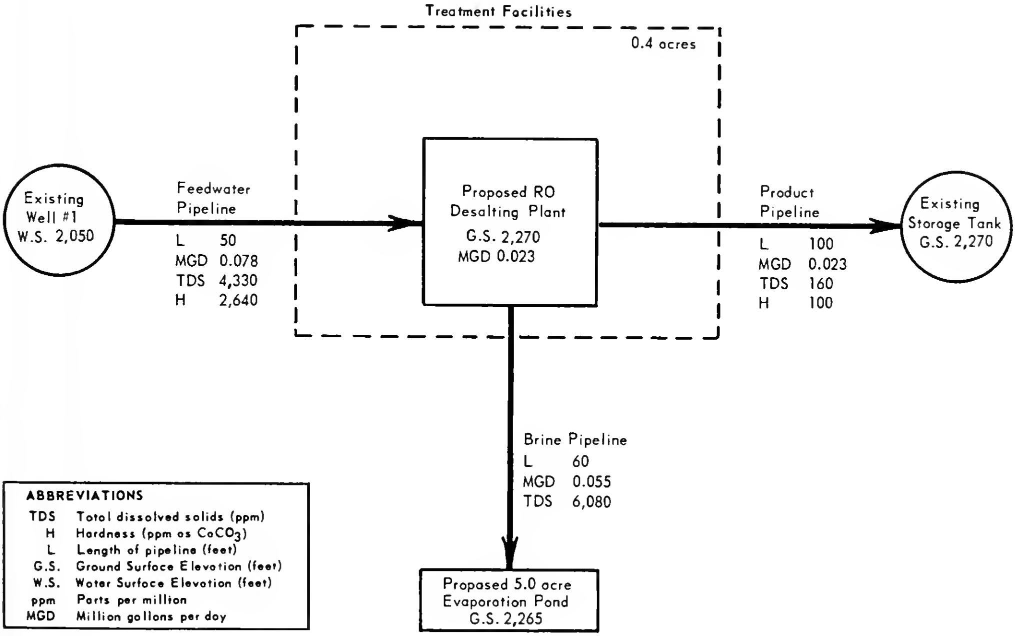


Figure 20. Schematic Diagram of Proposed Desalting Operation in Old Cuyama

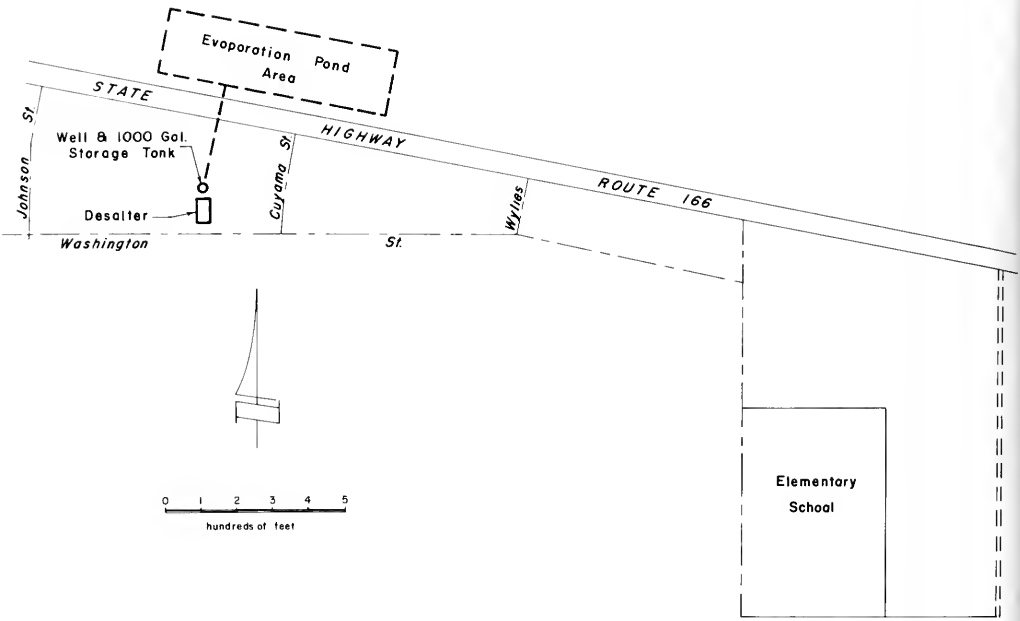


Figure 21. Location of Proposed Desalting Facilities at Old Cuyama

ter system. The locations of existing facilities and the proposed desalting facilities are shown in Figure 21.

As suggested by local representatives, the desalting plant could be located at the site of the water company well. Although the desalting plant would be located within the community, the building housing the desalter could be constructed to blend in with its surroundings and to muffle any excess noise.

An evaporation basin was selected as the most feasible method of brine disposal. The site for the basin suggested by local representatives is north of the community off Highway 166. The estimated net evaporation rate is 69 inches per year. At that rate, 5 acres of water surface would be required to dispose of the brines produced by reverse osmosis.

Benefits

The benefits that would result from improved water supplies at Old Cuyama are (1) a greater potential for increased residential development, resulting in increased land values; (2) decreased use of bottled water, water softeners, and washing materials; and (3) longer life of water-using appliances and pipelines.

Because of the poor-quality water supplies, the hoped-for development of Old Cuyama has been stopped. Although land for new homesites has already been subdivided, the Santa Barbara County Health Department has prohibited new water connections; as a result, no improvements are being made and land values are declining, particularly in view of the warning by the Health Department that local water supplies are unusable for domestic purposes. If good-quality water supplies were available, the development of the community could be continued.

Another benefit would result from the decreased requirement for bottled water and water softeners. At present, bottled water, at $1.45 per 5 gallons, must be used for drinking and cooking by residents and at the elementary school. Other benefits would result from both the longer lifetimes of appliances and pipelines and the decreased need for service and repairs, which are quite costly in the Cuyama Valley, because the nearest repair service is at Bakersfield some 50 miles away.

Still another benefit would result from the reduced need for soaps and washing powders. With the present community water supplies, some residents

use almost four times as much soap and detergents as would be needed with softer water. Moreover, clothing soon becomes discolored and deteriorates rapidly.

Feasibility

Either reverse osmosis or electrodialysis could be used to desalt the ground water at Old Cuyama. However, because of the high calcium-sulfate content of the ground water, the proportion of product water obtained would be relatively low and, as shown in Table 9, quite expensive. An alternative would be to create a community services district, along with New Cuyama, that would provide good-quality water supplies to both communities. Another alternative would be to purchase desalted water from New Cuyama and transport it to Old Cuyama by pipeline. As shown in Table 9, the cost of importing desalted water would be $2.06 per 1,000 gallons, including the cost of transportation.

The community has also considered use of the well at the elementary school. However, this does not appear to be feasible because the mineral content of the ground water from that well is high, and the only apparent advantage of using it as a source of supply would be the greater quantity obtained.

Table 9. Old Cuyama: Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 3,970,000 gallons
Peak daily requirements .... 23,000 gallons
Annual desalting plant load factor .... 47 percent

Output	Process: Reverse Osmosis 1/	Process: Reverse Osmosis 2/	Process: Electrodialysis 1/	Process: Electrodialysis 2/	Imported from New Cuyama
Annual output (millions of gallons)	3.97	3.97	3.97	3.97	3.97
Peak daily output (millions of gallons)	0.023	0.023	0.023	0.023	0.023
Characteristics of product water					
TDS (ppm)	500	164	500	164	308
Hardness (ppm as $CaCO_3$)	305	100	305	100	100
Costs					
Capital costs ($1,000s)	111	115	144	148	
Annual costs ($1,000s)					
Capital	7.6	7.9	9.9	10.1	
Operations and maintenance	9.3	9.4	10.1	10.2	
Replacement	0.4	0.4	0.8	0.8	
Total	17.3	17.7	20.8	21.1	
Cost of product water per 1,000 gallons ($s)					
Capital	1.92	1.99	2.49	2.55	
Operations and maintenance	2.34	2.37	2.55	2.57	
Replacement	0.10	0.10	0.20	.20	
Total	4.36	4.46	5.24	5.32	2.06
Land requirement (acres)	5.7	6.2	5.6	6.1	0

[1] For degree of treatment required to reduce TDS to 500 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 100 ppm.

New Cuyama

Summary of Assessment for New Cuyama

	Quantity, mgd	*Quality, ppm of TDS*	*Desalting Cost, $ per 1,000 gals.*
Desalted Water	0.34	150	1.31
Raw (untreated) Water Used For Blending	0.46	750	
Total Blended Product	0.80	500	0.56
Capacity of Desalting Plant	0.34 mgd		
Annual Desalting Plant Load Factor	43 percent		

Data is for the lowest cost method of achieving the criteria desired by New Cuyama. Schematic drawing of the physical arrangements is shown in Figure 23, and data on alternative methods are shown in Table 13 and in Appendix A.

New Cuyama is located about 4 miles west of Old Cuyama on Highway 166 (Figure 2). As explained in the preceding section, the two towns are the only developed communities in the Cuyama Valley.

New Cuyama, which was developed in 1951 by the Richfield Oil Company (now the Atlantic Richfield Company) in support of the South Cuyama oil fields, is a planned community of about 800 persons. The town consists of about 200 homes, community service facilities, Atlantic Richfield Company facilities, and a 4,000-foot air strip. A public high school with a 1973 enrollment of 83 is located nearby. Until recently, the water-supply and waste-disposal facilities for New Cuyama were operated by Atlantic Richfield. However, most of the homes in the community are individually owned.

In 1973, New Cuyama was sold to the Foundation for Airborne Relief, a nonprofit organization tha provides aid in disaster situations around the world. The long-range plan of the Foundation is to move its world headquarters from Long Beach to New Cuyama and to establish a flight-training school and a disaster-relief training program there.

Water Supply

New Cuyama has a municipal water supply system and a waste water disposal system. The present water supplies are obtained from three wells about 500 feet deep, located at the edge of the community. Two of the wells are operated as the primary and secondary sources of water, and the third provides peak and emergency flows. The water level in all three wells is about 170 feet below ground surface; however, the salt concentration and characteristics of the water in these wells, which are about 2,000 feet apart, are quite different. A 40,000-gallon storage tank, and desanding and chlorination facilities, are located near the primary well. Although the community water system was designed to serve the high school, the school has a separate well and water system.

A comparison of Tables 8 and 10 indicates that the ground water available in New Cuyama has a lower TDS concentration than that in Old Cuyama. This difference in water quality is partially attributed to the relative position of the two communities on the valley floor. Old Cuyama is located near the center of a wider part of the valley, where heavier agricultural development and ground water pumping have resulted in a cone of depression. New Cuyama is closer to the southern edge of the valley, where the valley is narrower and the ground water is influenced by subsurface inflows at the edge of the valley floor. There is no cone of depression at New Cuyama; instead, the ground water generally flows toward the surface drainage outlet at the western edge of the valley.

Alternative water supplies for New Cuyama may be available from wells located about 1.25 miles from the community. As shown by a comparison of Tables 10 and 11, ground water in these wells is of better quality than that pumped from the community wells.

The Salt Problem

The water supply system in New Cuyama is presently operated under a permit from the California Department of Public Health. However, the Santa Barbara County Health Department has prohibited new service connections until the quality of the water supply is improved. Before the community was sold, the oil company had recognized the water quality problem and was considering desalting and a dual water supply system.

The results of a water quality analysis of a sample from the primary well are shown in Table 10. Hardness and the concentrations of TDS and sulfates exceed the recommended levels in domestic water supplies. However, there is no nitrate problem (as there is in Old Cuyama). The average quality of

Table 10. Average Chemical Composition of Water Supply in New Cuyama

Constituent	*ppm*
Bicarbonate, HCO_3	175
Carbonates, CO_3	–
Chloride, Cl	30
Fluorides, F	–
Nitrate, NO_3	14
Nitrites, NO_2	–
Phosphate, PO_4	0.07
Sulfate, SO_4	933
Sulfides, S	–
Silica, SiO_2	19
Arsenic, As	–
Boron, B	–
Calcium, Ca	148
Copper, Cu	0.005
Iron, Fe	1.1
Magnesium, Mg	70
Manganese, Mn	–
Potassium, K	5
Selenium, Se	–
Sodium, Na	123
Hardness as $CaCO_3$	657
Total Dissolved Solids	1,469
pH	7.2
Conductivity (micromhos per cm)	2,150

– Not analyzed

Table 11. Average Chemical Composition of Alternative Water Supplies at New Cuyama

Constituent	*ppm*
Bicarbonate, HCO_3	168
Carbonates, CO_3	6
Chloride, Cl	18
Fluorides, F	0.44
Nitrate, NO_3	0.6
Nitrites, NO_2	0.002
Phosphate, PO_4	–
Sulfate, SO_4	402
Sulfides, S	<0.1
Arsenic, As	0.03
Boron, B	0.18
Calcium, Ca	70
Copper, Cu	–
Iron, Fe	<0.07
Magnesium, Mg	17
Manganese, Mn	0.03
Potassium, K	4.9
Selenium, Se	–
Sodium, Na	156
Hardness as $CaCO_3$	245
Total Dissolved Solids	754
pH	8.1
Conductivity (micromhos per cm)	–

– Not analyzed

ground water from the alternative wells outside the community is presented in Table 11.

Atlantic Richfield Company had been subsidizing the purchase of bottled water for cooking and drinking and had delivered water through the community distribution system without charge. However, the new owners have discontinued the subsidy and are charging for water and sewer service.

The TDS concentration in water from the wells at the alternative site ranges from about 680 ppm to 800 ppm, sulfate ranges from about 360 ppm to 430 ppm, and hardness from about 230 ppm to 270 ppm. Although the sulfate concentration is less than one half the concentration of 933 ppm in the present water supplies, it still exceeds the recommended USPHS maximum of 250 ppm in drinking water. Therefore, even if these new water supplies become available, bottled water may still be required for cooking and drinking.

Desalting Application

Community representatives have suggested that a desalting plant could be constructed at the site of the existing water treatment facilities as shown in Figure 22. An evaporation basin to dispose of brines could be located near Highway 166 between the county park and the high school. However, because a disposal basin at this location might be undesirable, the representatives have recommended an alternative location on the north side of the highway. Figure 23 is a block diagram that shows how the desalting facilities could be incorporated into the existing water supply system if water from the alternative wells were used.

Also considered was a combined treatment facility to serve both New Cuyama and Old Cuyama. The estimated cost of desalting the water from the alternative wells in New Cuyama is \$0.56 per 1,000 gallons compared with \$4.46 per 1,000 gallons in Old Cuya-

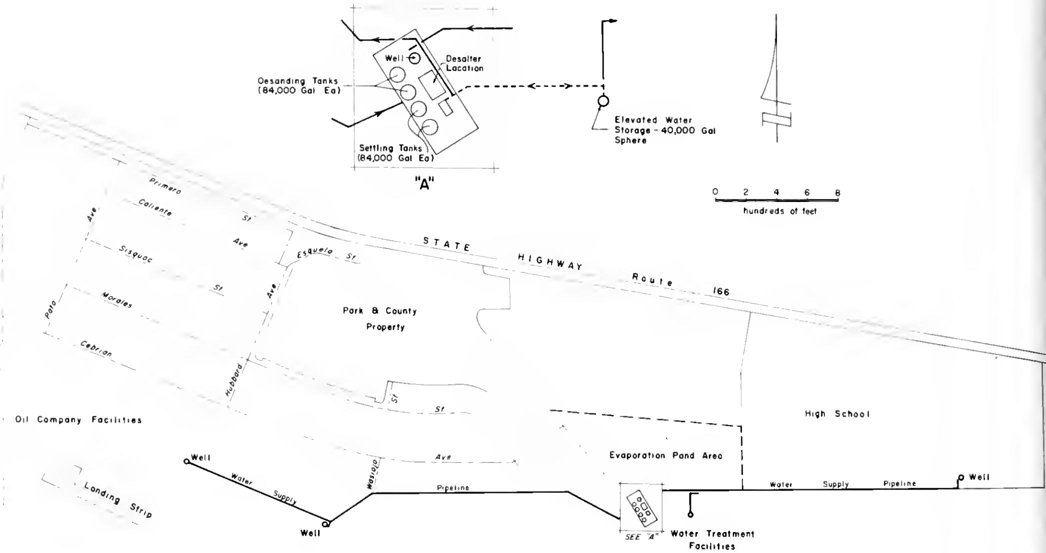


Figure 22. Location of Proposed Desalting Facilities at New Cuyama

ma. The lower cost of treatment at New Cuyama is due to the better quality water available there. That is, the TDS concentration in ground water at Old Cuyama is about three times as great, and the hardness is about four times as great, as that in the water at New Cuyama. Furthermore, the quantity of water used in Old Cuyama is only about 3 percent of that in New Cuyama.

Benefits

The benefits that would result from providing good-quality water supplies in New Cuyama include (1) decreased use of bottled water and water softeners, (2) a reduced need for soaps and washing powders, and (3) increased service life of water heaters.

The consumption of bottled water ranges from 4 to 6 gallons weekly per person; the cost of bottled water is $0.95 for 5 gallons. (While Atlantic Richfield Company was subsidizing the use of bottled water, the cost was $0.75 for 5 gallons.) Water softeners, most of them the exchange type, are used in about 50 percent of the homes at New Cuyama. The units must be exchanged about every two weeks at a cost of about $13 per month.

Unless a water softener is used, the service life of a residential water heater with a 5-year guarantee is only about 4 years; with soft water, the average service life is about 6 years. An exception in New Cuyama is a local restaurant, where the water heater is operated at a very high temperatures and must be replaced every year.

Feasibility

The most feasible method of desalting the present water supply in New Cuyama is by reverse osmosis at $0.94 per 1,000 gallons of product water. Other desalting processes and the unit costs of each are shown in Table 12. Because the salt concentration in the ground water is relatively low, distillation would not be feasible.

If ground water from the three alternative wells becomes available, it may be the most feasible source of water for New Cuyama. However, the combined output of the three wells would have a TDS concentration of 750 ppm and hardness as $CaCO_3$ of 245 ppm, well above the recommended levels of 500 ppm TDS and 100 ppm of hardness. As shown in Table 13, desalting this water by reverse osmosis would cost $0.80 per 1,000 gallons. If water from the alternative wells becomes available, the ground water now being used could be held in reserve for use as a backup supply.

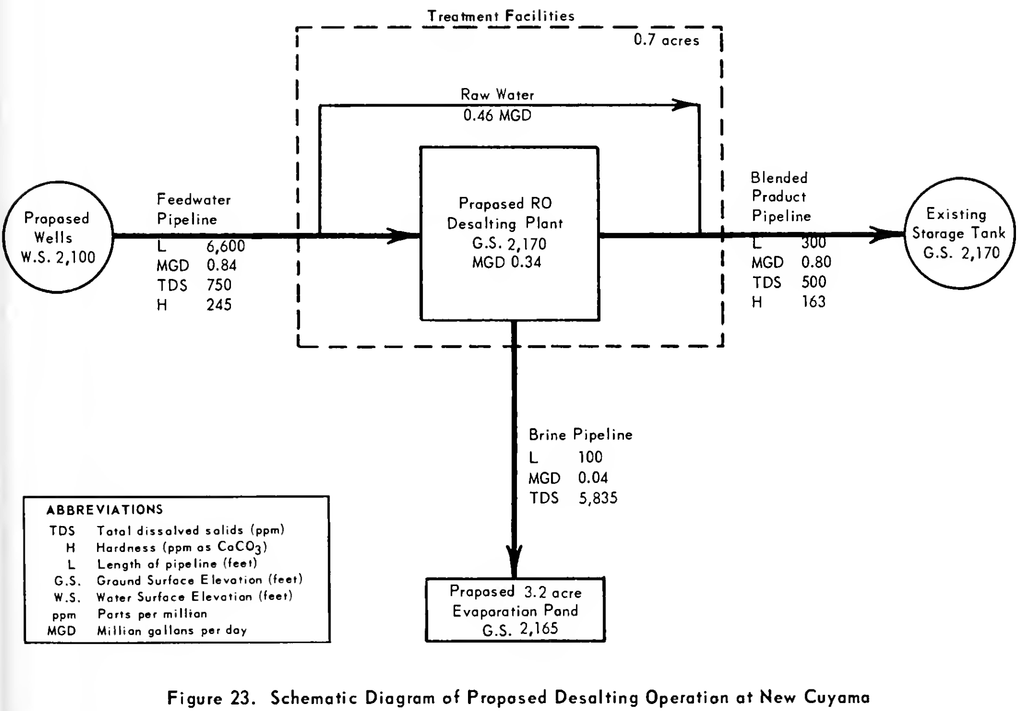


Figure 23. Schematic Diagram of Proposed Desalting Operation at New Cuyama

Table 12. New Cuyama (Existing Wells): Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 125,000,000 gallons
Peak daily requirements .... 800,000 gallons
Annual desalting plant load factor .... 43 percent

Output	Process				
	Reverse Osmosis		Electrodialysis		Ion Exchange
	1/	2/	1/	2/	
Annual output (millions of gallons)					
Desalted	92	118	125	125	125
Raw	33	7	0	0	0
Total blended product	125	125	125	125	125
Peak daily output (millions of gallons)					
Desalted	0.59	0.76	0.80	0.80	0.80
Raw	0.21	0.04	0	0	0
Total blended product	0.80	0.80	0.80	0.80	0.80
Characteristics of blended product					
TDS (ppm)	500	224	500	224	500
hardness (ppm as $CaCO_3$)	224	100	224	100	–
Costs					
Capital costs ($1,000s)	802	989	1,116	1,517	1,261
Annual costs ($1,000s)					
Capital	55.1	68.0	76.7	104.3	86.6
Operations and maintenance	52.9	62.2	56.9	60.6	73.0
Replacement	9.2	11.8	15.5	27.7	11.1
Total	117.2	142.0	149.1	192.6	170.6
Cost of blended product per 1,000 gallons ($s)					
Capital	0.44	0.54	0.61	0.83	0.69
Operations and maintenance	0.43	0.50	0.46	0.49	0.58
Replacement	0.07	0.10	0.12	0.22	0.09
Total	0.94	1.14	1.19	1.54	1.36
Land requirement (acres)	24.6	31.4	24.4	31.2	75.3

[1] For degree of treatment required to reduce TDS to 500 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 100 ppm.

Table 13. New Cuyama (Alternative Wells): Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 125,000,000 gallons
Peak daily requirements .... 800,000 gallons
Annual desalting plant load factor .... 43 percent

Output	*Process*			
	Reverse Osmosis		*Electrodialysis*	
	1/	2/	1/	2/
Annual output (millions of gallons)				
Desalted	53	92	118	125
Raw	72	33	7	0
Total blended product	125	125	125	125
Peak daily output (millions of gallons)				
Desalted	0.34	0.59	0.76	0.80
Raw	0.46	0.21	0.04	0
Total blended product	0.80	0.80	0.80	0.80
Characteristics of blended product				
TDS (ppm)	500	308	500	308
hardness (ppm as $CaCO_3$)	163	100	163	100
Costs				
Capital costs ($1,000s)	390	607	647	899
Annual costs ($1,000s)				
Capital	26.7	41.6	44.4	61.7
Operations and maintenance	37.4	49.7	44.3	47.9
Replacement	5.3	9.2	4.8	12.4
Total	69.4	100.5	93.5	122.0
Cost of blended product per 1,000 gallons ($s)				
Capital	0.22	0.33	0.36	0.50
Operations and maintenance	0.30	0.40	0.35	0.38
Replacement	0.04	0.07	0.04	0.10
Total	0.56	0.80	0.75	0.98
Land requirement (acres)	4.4	6.8	11.5	13.4

[1] For degree of treatment required to reduce TDS to 500 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 100 ppm.

Havasu

Summary of Assessment for Havasu

	Quantity, mgd	*Quality, ppm of TDS*	*Desalting Cost, $ per 1,000 gals.*
Desalted Water	0.06	250	4.67
Raw (untreated) Water Used For Blending	0.04	1,700	
Total Blended Product	0.10	800	2.80
Capacity of Desalting Plant	0.06 mgd		
Annual Desalting Plant Load Factor	20 percent		
Data is for the lowest cost method of achieving the criteria desired by Winterhaven. Schematic drawing of the physical arrangements is shown in Figure 25, and data on alternative methods are shown in Table 15 and in Appendix A.			

Havasu is a recently developed residential community in the rolling, semiarid terrain of eastern San Bernardino County (Figure 2). The present population is 220, about 60 percent of whom are retired. The community, which lies about 26 miles south of Needles and 19 miles northwest of Parker Dam, is being developed for vacation and retirement living on the west shore of Lake Havasu, a 45-mile-long reservoir formed by Parker Dam on the Colorado River. Havasu is about 1,000 feet west of the lake; between the community and the lake is Havasu Landing, a resort development with boat-docking facilities

Havasu is surrounded on the north, west, and south by the Chemehuevi Indian Reservation; except for a narrow strip of U. S. Government public land along the immediate lake shore, the reservation extends some 25 miles north and south of Havasu along the lake. Since 1965, the State of California has been considering the acquisition of land near Lake Havasu to be used for public recreation. The area under consideration includes the Whipple Mountains South of Havasu and the California shoreline of the Lake, extending from Havasu Landing southward to a point near Parker Dam.

Havasu has been laid out by a private developer to eventually provide 282 homesites for permanent and seasonal residents. Because of the dry climate and desert setting in which the new community is situated adjacent to the lake, the area has become extremely popular, particularly with residents of the Los Angeles area. Long-term annual precipitation records have varied from 0.2 inches to 9.3 inches. Annual temperature extremes have varied from a high of 124°F to a low of 21°F.

The nearby reservation lands have been the ancestral living ground for the Chemehuevi Tribe for many years—long before California became a State. Since about 1940, however, the Tribe has been scattered. Today, tribal leaders are attempting, with the assistance of federal programs, to reorganize the Tribe by providing housing and income opportunities on the reservation. To succeed in this effort, the tribal leaders will also have to obtain good-quality water supplies on the reservation.

Water Supply

The Havasu Water Company, which served about 40 customers during 1972, has been obtaining ground water from four wells with depths to water varying from 60 to 80 feet. The water yield of the alluvial soil, which has a high clay content, is quite low, while the water itself contains excessive concentrations of TDS and sulfate. The water company is trying to improve the quality of its water supplies and has drilled 20 new wells in search of better quality ground water.

The company has also considered the long-term use of surface water from Lake Havasu. Since mid 1973, the water company has been diverting water from the lake through use of perfected water rights leased from two other entities, with temporary access to the lake across leased federal land. The long-term value of these water rights to provide a reliable source of water for the company depends on the outcome of the dispute between California and Arizona over use of water from the Colorado River.

Until a decision on the leased water rights has been reached, the local ground water is the only long-term water supply controlled by the water company. Therefore, this study was conducted on the assumption that the ground water would be desalted to improve its quality.

The Chemehuevi Tribe holds water rights to 11,000 acre-feet per year from Lake Havasu, to be used exclusively for irrigation and domestic use on that part of the reservation immediately adjacent to the lake. In other parts of the reservation, the only source of water is poor-quality ground water. The use of lake water on reservation land could influence development in adjacent areas served by the water company.

The Salt Problem

The California Department of Health has established standards for drinking water in the Havasu area with the following limitations: TDS, 800 ppm; sulfate, 320 ppm; and fluorides, 1.0 ppm. (These limitations are very close to the concentration of minerals in Colorado River water.) For short-time or emergency use, the limitations may be exceeded to a maximum of 1,000 ppm TDS, 500 ppm sulfate, and 1.4 ppm fluorides. Water quality analyses of samples from each of the three wells used by the Havasu Water Company (Table 14) show that mineral concentrations in the local ground water exceed these temporary standards.

In 1972, the California Department of Health issued a temporary permit enabling the Havasu Water Company to deliver domestic water pumped from the wells with a proviso that the water quality be improved. More recently, the water company applied to the California Public Utilities Commission for authority to extend water service to additional areas. However, the application was suspended until the company can provide for delivery of sufficient quantities of potable water.

In an effort to improve the quality of its water supplies, the water company has purchased a previously used two-bed deionization unit, which can be reconditioned. The water company engineering consultant estimated that the unit can be used to economically desalt water with a TDS concentration ranging from 800 to 3,000 ppm and to produce 35,000 gallons of product water per day. The desalted water could then be blended with poor-quality ground water to produce some 52,000 gallons per day of acceptable water supplies.

Table 14. Chemical Composition of Water Supply in Havasu

Constituent	ppm			
	Well #1	*Well #2*	*Well #3*	*Weighted Average*
Bicarbonate, HCO_3	185	103	13	141
Carbonates, CO_3	0	0	0	0
Chloride, Cl	234	138	148	194
Fluorides, F	1.1	1.6	0.7	1.2
Nitrate, NO_3	4.8	0	0	3
Nitrites, NO_2	–	–	–	–
Phosphate, PO_4	–	–	–	–
Sulfate, SO_4	904	685	502	793
Sulfides, S	–	–	–	–
Arsenic, As	–	–	–	–
Boron, B	–	–	–	–
Calcium, Ca	220	146	78	182
Copper, Cu	–	–	–	–
Iron, Fe	0.05	0.75	0.12	0.3
Magnesium, Mg	34	18	13	27
Manganese, Mn	0	0.05	0.02	0.02
Potassium, K	9	6	5	8
Selenium, Se	0.005	0	0	0.003
Sodium, Na	345	248	252	304
Hardness as $CaCO_3$	689	440	250	564
Total Dissolved Solids	1,995	1,365	1,105	1,702
pH	8.0	7.9	7.8	7.9
Conductivity (micromhos per cm)	–	–	–	–

– Not analyzed.

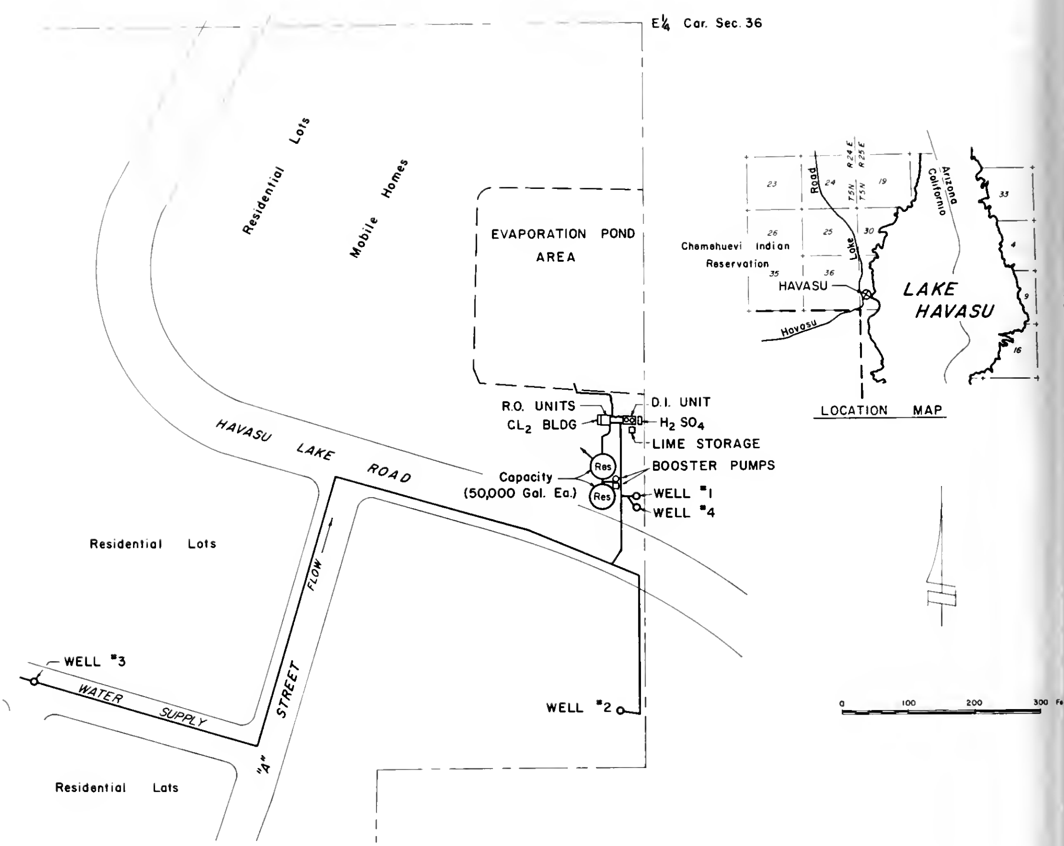


Figure 24. Location of Proposed Desalting Facilities at Havasu

Desalting Application

For this investigation, the Department of Water Resources evaluated three desalting processes, ion exchange, reverse osmosis, and electrodialysis, for a 100,000-gallon-per-day desalting unit. The water company has considered the initial installation of a smaller reverse osmosis unit, and would use the deionization unit to provide additional capacity to meet peak demands.

The location of the proposed 100,000-gpd unit studies by the Department of Water Resources, and other water supply facilities, are shown in Figure 24. A flow diagram of the proposed desalting process, using reverse osmosis, is presented in Figure 25.

The desalting plant could be housed in a building about the size of a residential garage, and, because it would be constructed at the base of a hill, the plant would not produce significant adverse environmental impact. Excess noise could be muffled by the desalter housing.

The consultant for the water company has recommended that the brine evaporation basin be located at the top of the slope above the desalting plant. Although the basin would be located at the edge of

the community, it would also be bounded on two sides by land set aside for mobile homes. At this location, the basin might produce an unfavorable environmental impact for nearby residents. If the basin were located farther from the community, a longer pipeline would be needed to transport brines from the desalter. However, the increased cost of the longer pipeline would be adequately compensated for by the improved appearance of the community.

Benefits

Good-quality water supplies would enable the Havasu Water Company to meet the requirements of the California Department of Health. Moreover, as soon as the water company can deliver good-quality water, land values will rise, and residents will benefit from the reduced need for soaps, washing powders, and bottled water.

As explained in the preceding paragraphs, land has been subdivided in the area for residential use. However, without satisfactory water service, the proposed developments in Havasu could come to a stand-still.

With good-quality water, residents would be able to reduce the use of soaps and washing powders by one-half to one-third. Bottled water would no longer be required for cooking and drinking. The average weekly consumption of bottled water in Havasu ranges from 7 gallons per person in the winter to 10 gallons per person in the summer, at a delivered cost of $2.50 for 5 gallons. The use of a water softener in Havasu costs about $15 per month; at present, only eight homes are equipped with a water softener.

Another benefit would result from the increased life of pipes, plumbing fixtures, and appliances. The poor-quality ground water distributed in Havasu also stains and discolors plumbing fixtures, mirrors, etc.

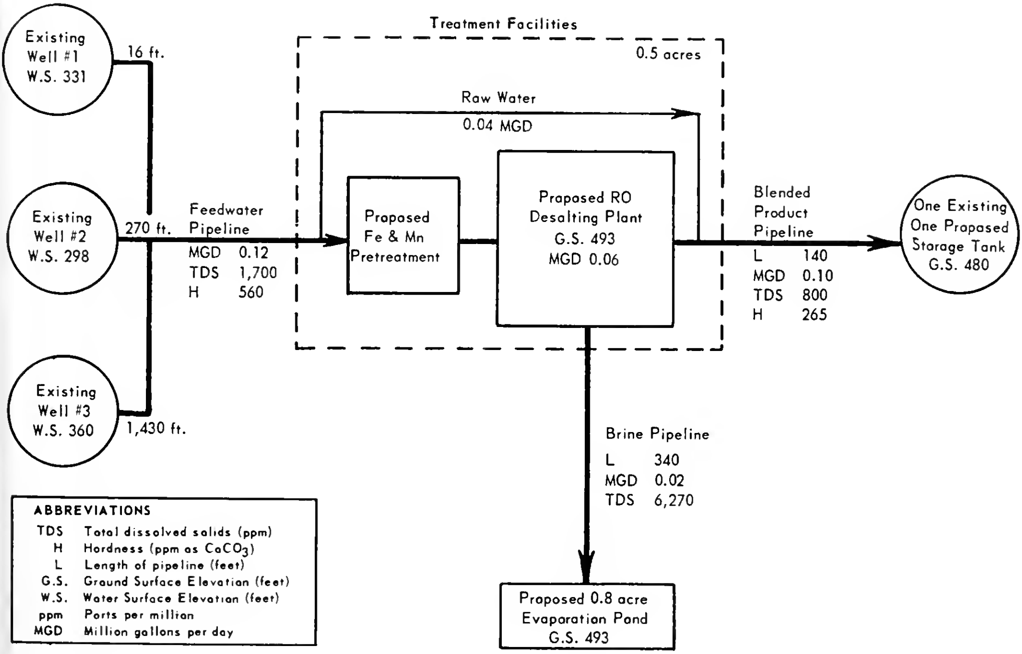


Figure 25. Schematic Diagram of Proposed Desalting Operation at Havasu

Feasibility

The results of analyses of desalting by reverse osmosis, electrodialysis, and ion exchange are presented in Table 15. At the present time, the water company is temporarily using water from Lake Havasu through use of leased water rights and temporary access to the lake. However, if water from the lake is insufficient, or not available in the future, to meet local water requirements, desalting of the local ground water could provide potable water supplies for Havasu.

Table 15. Havasu: Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 7,210,000 gallons
Peak daily requirements .... 100,000 gallons
Annual desalting plant load factor .... 20 percent

Output	Process				
	Reverse Osmosis		Electrodialysis		Ion Exchange
	1/	2/	1/	2/	
Annual output (millions of gallons)					
Desalted	4.33	7.21	5.05	7.21	5.05
Softened	0	0	0	0	1.08
Raw	2.88	0	2.16	0	1.08
Total blended product	7.21	7.21	7.21	7.21	7.21
Peak daily output (millions of gallons)					
Desalted	0.06	0.10	0.07	0.10	0.70
Softened	0	0	0	0	0.015
Raw	0.04	0	0.03	0	0.015
Total blended product	0.10	0.10	0.10	0.10	0.10
Characteristics of blended product					
TDS (ppm)	800	302	800	302	800
hardness (ppm as $CaCO_3$)	265	100	265	100	
Costs					
Capital costs ($1,000s)	109	155	139	247	222
Annual costs ($1,000s)					
Capital	7.5	10.6	9.6	16.9	15.2
Operations and maintenance	12.3	15.5	12.9	15.8	15.0
Replacement	0.4	0.7	1.6	3.2	3.9
Total	20.2	26.8	24.1	35.9	34.1
Cost of blended product per 1,000 gallons ($s)					
Capital	1.04	1.47	1.33	2.35	2.11
Operations and maintenance	1.70	2.15	1.79	2.19	2.08
Replacement	0.06	0.10	0.22	0.44	0.54
Total	2.80	3.72	3.34	4.98	4.73
Land requirement (acres)	1.4	2.0	1.2	1.8	4.3

[1] For degree of treatment required to reduce TDS to 800 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 100 ppm.

Winterhaven

Summary of Assessment for Winterhaven

	Quantity, mgd	*Quality, ppm of TDS*	*Desalting Cost, $ per 1,000 gals.*
Desalted Water	0.235	150	1.17
Raw (untreated) Water Used For Blending	0.020	1,370	
Total Blended Product	0.255	245	1.08
Capacity of Desalting Plant	0.255 mgd		
Annual Desalting Plant Load Factor	57 percent		
Data is for the lowest cost method of achieving the criteria desired by Winterhaven. Schematic drawing of the physical arrangements is shown in Figure 27, and data on alternative methods are shown in Table 17 and in Appendix A			

Winterhaven is an isolated residential-commercial community in Imperial County at the southeastern border of California (Figure 2). The community, which occupies about 100 acres, is surrounded on the east, west, and north by the Fort Yuma Indian Reservation. On the south, Winterhaven is separated from Yuma, Arizona by the Colorado River, the Arizona-California boundary. U. S. Highway 80 passes through the center of Winterhaven and Interstate Highway 8, the main transportation link between San Diego and Arizona, runs along the edge of the community.

About one third of the population of some 800 are retired persons with low, fixed incomes. About 125 members of the community live in mobile homes or trailers.

The climate of southeastern California is semi-arid. Temperature extremes at Winterhaven range from about 20°F in the winter to summertime highs of about 120°F. Long-term annual precipitation has varied from 0.2 inches to 5.6 inches. Despite the lack of rainfall, irrigated crops are grown in the surrounding area, using Colorado River water from the All American Canal.

Both the water supply and the method of sewage disposal in Winterhaven are badly in need of improvement. At present, sewage is collected in cesspools and septic tanks, and the construction of new dwellings has been prohibited by court order until a sanitary waste collection system can be completed in 1974.

Actually, because the community is surrounded by the Indian Reservation and the river, very little room remains for expansion. However, owners of land between Interstate 8 and the river plan to develop a subdivision, with condominiums and a golf course, provided that the water supply and sewage systems are improved.

The Fort Yuma Indian Reservation is occupied by the Quechan Indians, who also want to develop sewage-disposal facilities and to expand and improve the water system serving the reservation. The Tribe has had engineering studies made of several projects, including a joint project to serve both the reservation and Winterhaven. Winterhaven has also conducted engineering studies that include alternative projects to serve both areas.

Water Supply

The Winterhaven County Water District, which includes about 125 acres, serves Winterhaven only with water from a single well. At present, the water system serves 201 connections; however, the Imperial County Health Department has prohibited additional connections until a sewage-collection system has been completed. The water contains high concentrations of TDS, manganese, and sulfates, and is very hard. A water quality analysis of a sample from the District well is presented in Table 16.

The well is about 150 feet deep and the water table stands at about 12 feet below ground surface. The water table has been progressively rising since the U. S. Bureau of Reclamation began serving the surrounding reservation lands with water from the All American Canal.

Alternative water supplies (other than desalting) that are being considered for use in Winterhaven include (1) continued use of the present well; (2) Colorado River water from the All American Canal, treated for use in Winterhaven only; (3) Colorado River water treated for use in both Winterhaven and the reservation; (4) new wells and storage facilities to serve both Winterhaven and the reservation; and (5) a new well and storage facilities to serve Winterhaven only. The water district plans to drill an exploratory well soon. Other facilities planned are new chlorination facilities and a 100,000-gallon storage tank.

Table 16. Chemical Composition of Water Supply in Winterhaven

Constituent	*ppm*
Bicarbonate, HCO_3	290
Carbonates, CO_3	0
Chloride, Cl	182
Fluorides, F	0.5
Nitrate, NO_3	–
Nitrites, NO_2	–
Phosphate, PO_4	–
Sulfate, SO_4	514
Sulfides, S	–
Arsenic, As	–
Boron, B	–
Calcium, Ca	148
Copper, Cu	–
Iron, Fe	0.06
Magnesium, Mg	46
Manganese, Mn	0.91
Potassium, K	4.3
Selenium, Se	–
Sodium, Na	208
Hardness as $CaCO_3$	560
Total Dissolved Solids	1,370
pH	7.8
Conductivity (micromhos per cm)	1,880

– Not analyzed.

Although a large-scale combined water system to serve both Winterhaven and the Indian Reservation would be advantageous, the initial cost of such a system would be high. A problem here is the different objectives of the two communities. Whereas Winterhaven, with a large number of retirees, has limited potential for growth, the Tribe is primarily interested in growth and the development of industries to provide job opportunities.

The Salt Problem

The municipal water delivered in Winterhaven causes numerous problems for homeowners. For example, washing machines and dishwashers require frequent repair because of sticking solenoid-type water valves. Water heaters must be replaced about every 5 years, whereas with softer water they are normally guaranteed for 10 years. The hard water also stains and discolors plumbing fixtures, faucets, and mirrors; and shower heads are continually plugged.

In addition, very few persons use the community water supplies for cooking and drinking, but instead purchase bottled water or "bulk" water usually delivered by truck. Those who use the bulk water must have a 100-gallon tank, which is usually connected to a third faucet in the kitchen. The delivered cost of bulk water is $0.13 per gallon; the average monthly cost per household is $14. The delivered cost of bottled water is $1.61 for 5 gallons. Average weekly consumption of bottled water ranges from 7 gallons per person in winter to 10 gallons per person in summer. Local restaurants also use the bulk water for cooking and drinking

Water softeners are used in about 10 percent of the homes in Winterhaven. Those who have them report a 50 percent savings in the cost of soaps and washing powders. The cost of owning and maintaining a water softener is about $10 per month.

Although not related to the excessive salts in the local ground water, the sewage disposal problem is equally serious in Winterhaven. The community engineering consultant has concluded that the development of both adequate water supplies and sewage disposal facilities is essential to both the future development of Winterhaven and the protection of health.

As stated in a preceding paragraph, the present method of sewage disposal presents a serious health hazard, and the Imperial County Health Department has prohibited new water connections until a sewage collection system has been constructed. The cesspools and septic tanks used by individuals do not function properly because of soil conditions, the high water table, and a lack of leeching areas. As long ago as 1961, the Health Department reported that 25 percent of the cesspools and septic tanks in Winterhaven were malfunctioning. In the business district, 85 percent of the sewage facilities are inoperable and must be pumped out from 1 to 5 times per month. Sewage flowing in some of the streets is not an uncommon sight.

Desalting Application

Ion exchange, electrodialysis, and reverse osmosis have been evaluated as desalting applications for Winterhaven. The results of these analyses are presented in Table 17. The location of the proposed desalting facilities and other water supply facilities are shown in Figure 26. A block diagram of the proposed desalting facilities is presented in Figure 27.

Evaporation is considered the best method for disposal of brines. Neither deep well disposal nor discharge into a waste water disposal system (after such a system is constructed) is considered feasible. Deep well disposal could lead to problems of (1) compatibility of the brines in deep aquifers, and (2) interconnection with fresh water aquifers. Discharge into a waste disposal system could also present a problem, because it has been proposed that waste water from Winterhaven and the Indian Reservation be combined and discharged into the Yuma Municipal waste water system, effluent from which is treated and discharged into the Colorado River. The salt concentration of the river already is high, and additional salt loadings would be unacceptable. Disposal to land would also be unacceptable, because the effluent might further degrade ground water.

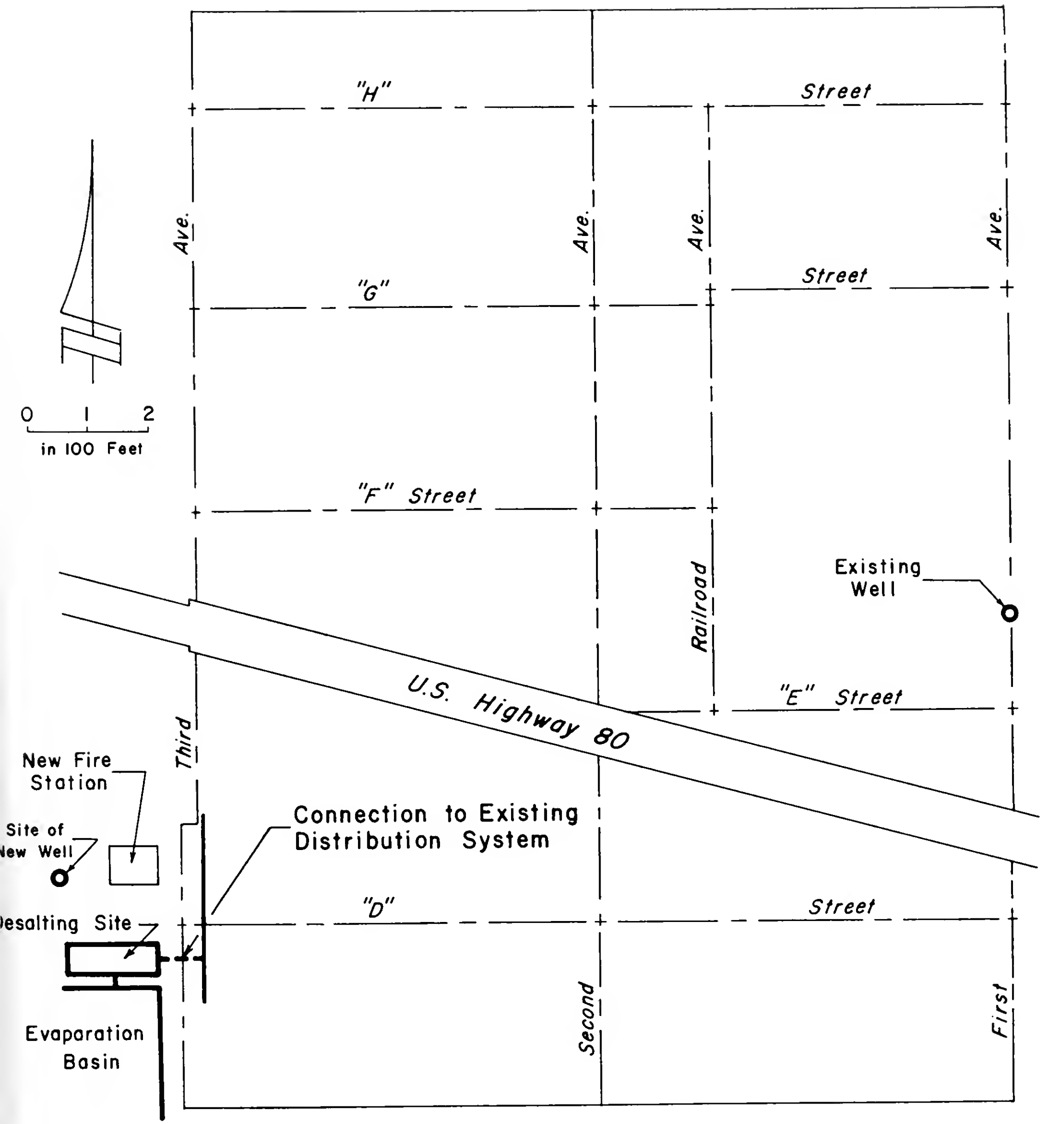


Figure 26. Location of Proposed Desalting Facilities at Winterhoven

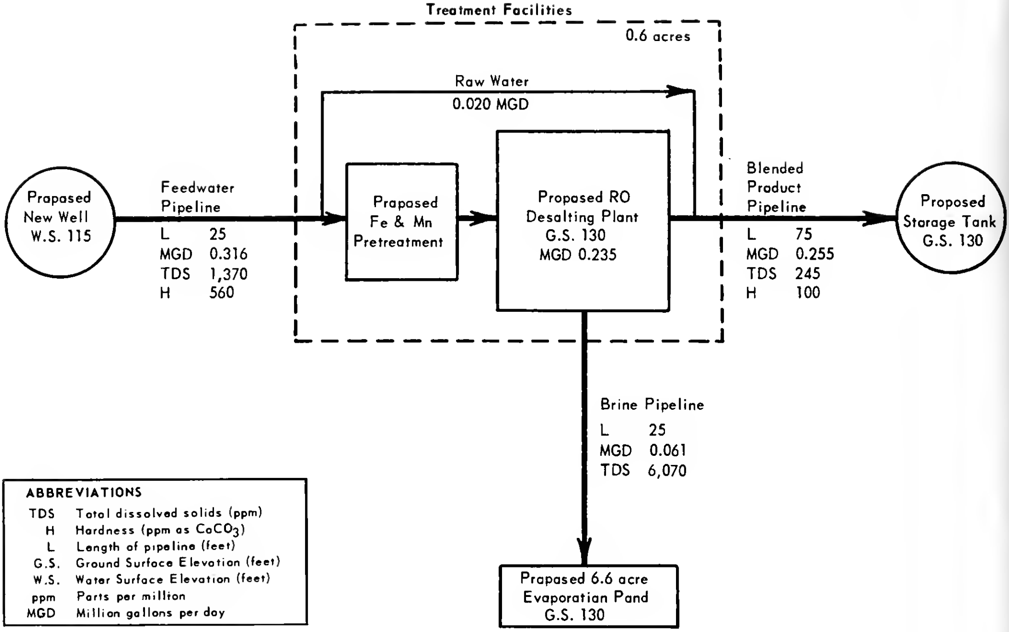


Figure 27. Schematic Diagram of Proposed Desalting Operation at Winterhaven

Disposal of the brine by evaporation would require 6.6 acres of open water surface. The estimated net annual evaporation rate is 72 inches. As shown in Figure 26, the evaporation basin would be constructed just adjacent to the desalting plant. However, because very little land remains for future expansion of the community, this location may not be available. An alternative site on nearby unused land, owned by the U. S. Bureau of Land Management, might be feasible, provided the cost of the longer brine pipeline would not be excessive.

Benefits

Improved water supplies in Winterhaven would (1) enable the construction of additional homes, (2) eliminate the need for water softeners, (3) extend the life of appliances, plumbing fixtures, and pipelines, (4) eliminate stains and discolorations, and (5) end the need for bulk and bottled water.

Feasibility

The feasibility of desalting in Winterhaven will depend on both the source of water supply and the financial assistance available to help construct the required facilities. The results of the evaluation of desalting applications in Winterhaven are presented in Table 17.

Desalting appears to be feasible, because the value of the benefits would apparently exceed the cost of desalting. The benefits cannot be evaluated in detail; however, elimination of the delivery of bulk water at $0.13 per gallon would result in a sizeable benefit in itself. Still, this benefit would be offset to some extent by the increased cost of the desalted water for all domestic uses; that is, the desalted water would be used not only for cooking and drinking but also for washing, bathing, and flushing toilets.

Alternative sources of improved water that might be available to Winterhaven include (1) a new water well, (2) the All American Canal, which passes about 4 miles from the community, or (3) the City of Yuma water supply, from the Yuma Main Canal, which passes about one-half mile east of Winterhaven and takes water from the All American Canal. However, certain factors might influence the acceptability of these alternatives: (1) Water from a new well may still contain excessive salts; (2) water in the All

American Canal is controlled by the Imperial Irrigation District and the Coachella Valley County Water District, for whom the water was initially diverted, and may not be available.

Still another source of water may be available to Winterhaven. Recently, several California entities that border on the Colorado River have been trying to form a new water district. Their objective is to obtain rights to use the river water through exchange agreements with the holders of prior rights. If the new district were formed, it might provide an additional source of water for Winterhaven.

Even though the unit cost of desalting the present ground water appears to be feasible, Winterhaven would still require assistance in financing the capital cost of the required facilities. At the present time, the community is trying to provide the badly needed sewage disposal system. The community engineering consultant has developed plans for a waste water collection and treatment system, and a federal grant to help finance the project has been approved.

The consultant has also recommended that new water supplies be obtained and that adequate distribution facilities be constructed.

Table 17. Winterhaven: Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 53,000,000 gallons
Peak daily requirements .... 255,000 gallons
Annual desalting plant load factor .... 57 percent

Output	Process				
	Reverse Osmosis		Electrodialysis		Ion Exchange
	1/	2/	1/	2/	
Annual output (millions of gallons)					
Desalted	37	49	53	53	35
Softened	0	0	0	0	9
Raw	16	4	0	0	9
Total blended product	53	53	53	53	53
Peak daily output (millions of gallons)					
Desalted	0.180	0.235	0.255	0.255	0.170
Softened	0	0	0	0	0.042
Raw	0.075	0.020	0	0	0.043
Total blended product	0.255	0.255	0.255	0.255	0.255
Characteristics of blended product					
TDS (ppm)	500	245	500	245	500
hardness (ppm as $CaCO_3$)	204	100	204	100	100
Costs					
Capital costs ($1,000s)	284	347	501	521	541
Annual costs ($1,000s)					
Capital	19.5	23.7	34.4	35.7	37.0
Operations and maintenance	24.4	28.8	28.1	28.2	33.3
Replacement	3.7	4.9	6.3	6.3	5.4
Total	47.6	57.4	68.8	70.2	75.7
Cost of blended product per 1,000 gallons ($s)					
Capital	0.37	0.45	0.65	0.67	0.45
Operations and maintenance	0.46	0.54	0.53	0.53	0.54
Replacement	0.07	0.09	0.12	0.12	0.09
Total	0.90	1.08	1.30	1.32	1.08
Land requirement (acres)	6.5	8.2	6.0	8.0	28.4

[1] For degree of treatment required to reduce TDS to 500 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 100 ppm.

Marin County

Summary of Assessment for Marin Municipal Water District

	Quantity, mgd	*Quality, ppm of TDS*	*Desalting Cost, $ per 1,000 gals.*
Desalted Water	3.5	50	1.71
No blending			
Feedwater	—	15,200	
Capacity of Desalting Plant ... 3.5 mgd			
Annual Desalting Plant Load Factor ... 67 percent			
Data is for the lowest cost method of achieving the criteria desired by Marin MWD. Schematic drawing of the physical arrangements is shown in Figure 29, and data on alternative methods are shown in Table 19 and in Appendix A.			

The southern part of Marin County is a peninsula bordered on the west by the Pacific Ocean and on the east by San Francisco Bay (Figure 2). The county is separated on the south from San Francisco by the Golden Gate. U. S. Highway 101, which crosses the Golden Gate Bridge, connects the residential communities of Marin County with San Francisco and other Bay area business centers. The Richmond-San Rafael Bridge provides access to the East Bay communities.

Most of the commercial and industrial development in Marin County is located near the shore of San Francisco Bay on the eastern side of the county, as is most of the residential development. The northwestern part of the county and the western slopes are sparsely populated and are used principally for agriculture.

Water Supply

Two large water districts provide most of the water in Marin County. The Marin Municipal Water District serves the southeastern part of the county, where most of the population is concentrated. The source of water supply for the District is surface runoff, which is impounded in five main reservoirs in the hills west of the service area.

The population within the service area of the Marin Municipal Water District has grown from about 70,000 in 1950 to some 170,000 in 1970, one of the largest rates of growth in the Bay area during this period. Recently, however, the rate of growth in Marin County has declined, as reflected in a drop in school attendance during the past four years. The present population projections in the county general plan are lower than those of earlier projections.

The population of Marin County will probably continue to grow, although at a slow rate, and create an increased demand for water. Per capita use of water in the District has increased from 140 gallons per day to over 160 gallons per day during the past 10 years. However, the District believes that per capita use will be stabilized at the present rate because water conservation practices have become more effective.

The Water Problem

The sources of local water supply available to the Marin Municipal Water District have been almost fully developed. Although the relatively high precipitation in the county has always provided adequate runoff, the present demand exceeds the safe yield of present supplies from the watershed area. Therefore, the District is now investigating alternative sources, including (1) reclaimed waste water, (2) local and imported water, and (3) desalted sea water from either the ocean or San Francisco Bay.

Waste water could be treated at any of the several waste water disposal facilities within the District. Although waste water reclamation would enable more efficient use of existing water supplies, direct use of the reclaimed water would probably be limited. Good-quality surface water could be imported from Walker Creek in northern Marin County, or from the Russian River in Sonoma County.The District has estimated the following costs for these alternatives:

1. Reclaimed waste water: $300 per acre-foot, or $0.92 per 1,000 gallons (not for direct domestic use).
2. Imports from Walker Creek: $166 per acre-foot, or $0.51 per 1,000 gallons.
3. Imports from Russian River: $150 per acre-foot, or $0.46 per 1,000 gallons.

The cost of water from the District's present water system, based on the cost of installed facilities, is $55 per acre-foot or $0.17 per 1,000 gallons.

Recognizing the economies of large-scale development, the District has twice proposed a plan to import water from the Russian River in Sonoma County on a staged basis. However, in the November 1973 election, and for the second time in two years, the plan was rejected by Marin Municipal Water District voters. The proposed plan would have made increased supplies available to meet present commitments for water.

As desalting was one option already being considered by the District to meet their water supply needs, the District desired to be included as one of the communities in this desalting assessment study.

Desalting Applications

Two sources of sea water are readily available in Marin County—the Pacific Ocean and San Francisco Bay. Sea water could be taken from the ocean, treated in an on shore desalting plant, and transported over the mountains to southeastern Marin County, where the water would be used. On the other hand, a desalting plant on San Francisco Bay would be more practical for two reasons: (1) The water is needed in areas of heavy population just adjacent to the Bay, and (2) the salt concentration in the Bay is much lower than that of the ocean, particularly in the upper reaches of the Bay, which are some distance from the Golden Gate, where tidal action carries sea water into the Bay. The overflow from the Central Valley discharges into the northeast corner of the Bay and dilutes the salt concentration.

Municipal waste water is treated at several treatment plants at various locations within the District. The treated water is presently discharged into the Bay; however, there is some interest in reusing waste water in the area. Unless the treated water contained excessive concentrations of minerals, the treated water could be used for approved purposes without desalting.

For the reasons stated in the preceding paragraphs, this study was limited to desalting of Bay water. The Marin Municipal Water District has expressed interest in a desalting plant at Point San Quentin near San Quentin State Penitentiary. Other locations fronting on San Francisco Bay would be less feasible, because the extensive mud flats surrounding much of the bay shore would increase the cost of intake and discharge facilities. The average salt composition of the Bay water near Point San Quentin is shown in Table 18. (However, the concentration of salts in the Bay water at this location varies with the season.)

A second factor favoring this location is the fact that a regional waste water treatment plant may soon be constructed at San Quentin Point, and the joint operation of a desalter and a waste water treatment facility could be advantageous. For instance, the temperature and salt concentration of the hot water and brines discharged from the desalter will be considerably higher than those of the Bay water. And, a 1972 regulation of the State Water Resources Control Board prohibits ". . .thermal waste discharges (into the Bay) having a maximum tempera-

Table 18. Chemical Composition of San Francisco Bay near Point San Quentin

Constituent	*ppm*
Bicarbonate, HCO_3	111
Carbonates, CO_3	–
Chloride, Cl	8,000
Fluorides, F	–
Nitrate, NO_3	–
Nitrites, NO_2	–
Phosphate, PO_4	–
Sulfate, SO_4	600
Sulfides, S	–
Arsenic, As	–
Boron, B	0.8
Calcium, Ca	155
Copper, Cu	–
Iron, Fe	–
Magnesium, Mg	523
Manganese, Mn	–
Potassium, K	164
Selenium, Se	–
Sodium, Na	4,400
Silica, SiO_2	12
Hardness as $CaCO_3$	2,530
Total Dissolved Solids	15,200
pH	7.8
Conductivity (micromhos per cm)	24,000

– Not analyzed.

ture greater than 4°F above the natural temperature of the receiving water. . . ." This means that discharges from the desalting plant would have to be cooled and diluted, which would increase the costs of desalting. All other discharge requirements ordered by the Board would also have to be complied with.

However, if heat from the effluent from the desalter were available for use in a waste water treatment plant, a twofold benefit could result:

1. A limited increase in the temperature of waste water will increase the efficiency of the bacterial (secondary) phase of treatment;
2. A combined effluent from both plants would have a lower mineral concentration than that from the desalter alone, and therefore would be less harmful to the plant and animal life of the Bay. That is, the temperature and salt concentration of a combined effluent would be more acceptable for discharge into San Francisco Bay.

The proposed location of desalting facilities on San Quentin Point, in relation to the existing water facilities, is shown in Figure 28. The only conveyance facilities included as part of the desalting facilities are the feedwater intake and the brine discharge. A schematic diagram of the proposed desalting operation is presented in Figure 29. Table 19 presents the results of analyses of the operation of the proposed plant on San Quentin Point. Because of the high salt concentration in the waters of the Bay, distillation was selected as the most suitable desalting process.

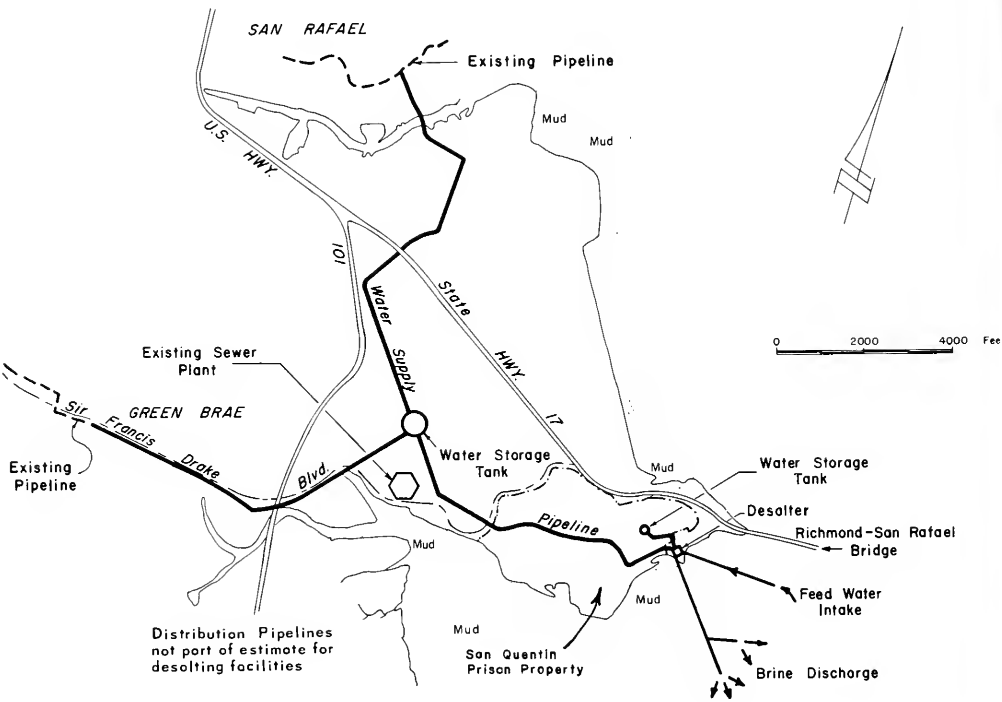


Figure 28. Location of Proposed Desalting Facilities in Marin Municipal Water District

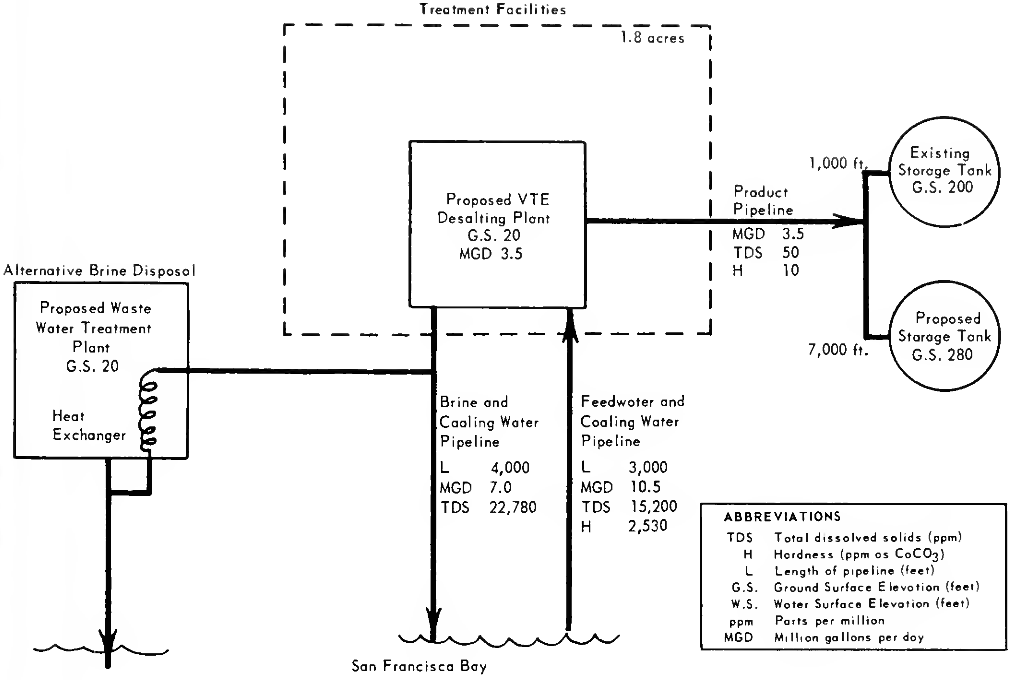


Figure 29. Schematic Diagram of Proposed Desalting Operation in Marin Municipal Water District

The desalting plant would have a minimum adverse impact on the surrounding environment. The facilities would be constructed near the site of the prison, in an area not used by the public and away from existing or potential residential development. Although the plant could be seen from the San Rafael-Richmond bridge, the facilities could be designed to have an attractive appearance. As explained in the preceding paragraphs, the temperature and salt concentration of discharged effluents would have to be controlled to prevent an adverse impact on the waters of the Bay.

Feasibility

Desalting of San Francisco Bay water to provide supplemental supplies in Marin County may be feasible if:

1. lower cost surface water is not available; or
2. there is sufficient value in constructing desalting facilities by stages, i.e., in modules, to match small increments of growth in water demands; or
3. there is sufficient value in developing more than one source of supplemental water by installing small desalting units along the shores of San Francisco Bay within the District; or
4. there is sufficient advantage in providing water-supply peaking capacity at specific locations along the Bay shore within the District.

Desalting, used in conjunction with existing surface water storage reservoirs, may also provide supplemental water to meet daily or annual peak demands. As described in the preceding paragraphs, a desalting plant and related facilities can be located entirely within the area of need. In addition, the output of the desalting facility can be staged to minimize annual costs and to provide only the amount of water needed to meet immediate needs.

At present, distillation is the only proven production process for desalting water of the high salinity of San Francisco Bay. The estimated unit cost of desalting Bay water by the process shown schematically in Figure 29 is $1.71 per 1,000 gallons.

Desalting of high-salinity water by reverse osmosis is now in the research and development stage. In small-scale tests using reverse osmosis, the salt concentration in sea water has been reduced to fresh water levels. As membranes are improved and production models developed, the cost of full-scale desalting of sea water by reverse osmosis is expected to be lower than the cost of the distillation process for certain applications.

Because they are constructed in modules, reverse osmosis systems can be assembled to provide a wide range of desalting capacities. Along the many miles of the Bay shore line bordering the District service area, there may be opportunities to desalt Bay water and provide supplemental water supplies to isolated areas within the District.

Table 19. Marin Municipal Water District: Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements	858,000,000 gallons
Peak daily requirements	3,500,000 gallons
Annual desalting plant load factor	67 percent

Output	*Vertical Tube Evaporation*
Annual output (millions of gallons)	858
Peak daily output (millions of gallons)	3.5
Characteristics of product water	
TDS (ppm)	50
hardness (ppm as $CaCO_3$)	8
Costs	
Capital costs ($1,000s)	5,964
Annual costs ($1,000s)	
Capital	407.7
Operations and maintenance	1,055.2
Replacement	0
Total	1,462.9
Cost of product water per 1,000 gallons ($s)	
Capital	0.48
Operations and maintenance	1.23
Replacement	0
Total	1.71
Land requirement (acres)	1.8

Refugio State Beach

Summary of Assessment for Refugio State Beach

	Quantity, mgd	*Quality, ppm of TDS*	*Desalting Cost, $ per 1,000 gals*
Desalted Water	0.02	200	3.23
No blending			
Feedwater	—	1,920	
Capacity of Desalting Plant	0.02 mgd		
Annual Desalting Plant Load Factor	50 percent		

Data is for the lowest cost method of achieving the criteria desired by Refugio State Beach. Schematic drawing of the physical arrangements is shown in Figure 30, and data on alternative methods are shown in Table 21 and in Appendix A.

Refugio State Beach in Santa Barbara County lies just outside the community of Capitan on U. S. Highway 101, about 20 miles north of Santa Barbara (Figure 2). Refugio adjoins El Capitan State Beach; the combined shoreline of both beaches is some 4.5 miles and provides a recreation area of 172 acres. Gaviota State Park, the subject of the next section of this chapter, is 4 miles north of Refugio.

The mild air and ocean temperatures permit year-around use of these beaches, which are especially popular with residents of nearby cities. Santa Barbara is nearby, and the northern suburbs of Los Angeles are only about 70 miles away.

All three recreation areas, Refugio, El Capitan, and Gaviota, are operated by the California Department of Parks and Recreation. At all three sites, programs are either underway or being planned to enlarge the recreation area and improve accommodations. The water supply at all three beaches is ground water from wells.. The water quality problems at Refugio and Gaviota State Beaches, respectively, are the subjects of this and the following section of this chapter. (El Capitan State Beach has no water quality problem.)

Water Supply

Water for use by visitors is pumped from a single well located near the landward boundary of the beach. The water is very brackish, with a TDS concentration of 1,915 TDS and hardness as $CaCO_3$ of 1,469 ppm. Ground faults in the area above the beach have segregated the ground waters, and the quality of water in various wells only a short distance apart can be significantly different. About 2 miles inland and upslope from the beach, several wells produce ground water with an average TDS concentrations of about 1,000 ppm. However, this water is already in use and may not be available as a source of supply for Refugio.

Water from the single well at Refugio is used for washing, drinking and cooking, and also for both irrigation of the park area and transportation of wastes. Waste water from each staff residence, and from the individual park rest rooms, is discharged into individual septic tanks. The effluent from each tank is collected and discharged to a common leach field. However, this system has not been satisfactory, and the Department of Parks and Recreation plans to construct a central waste water treatment plant.

The Department of Parks and Recreation is also having a test well drilled about 2 miles up Refugio Canyon to determine the quality of the ground water at that site. If the water proves to be usable, the Department may also develop a dual water system—one to carry treated water for cooking, drinking and washing, and another to carry untreated ground water for irrigation and disposal of wastes.

The Salt Problem

In 1971, the California Department of Health sampled the ground water at Refugio and advised that the water should no longer be used for human consumption and that a new source of good-quality water was essential. The quality of the ground water at Refugio is shown in Table 20.

Sewage disposal has also become a problem at Refugio, because, as explained previously, the capacity of the local system is inadequate. During the 1972 season, the Beach was closed to the public because of water-supply and sewage-disposal problems.

Desalting Application

Either brackish ground water or sea water is available for desalting at Refugio. However, the average salt concentration of sea water is almost 34,000 ppm, far higher than that of brackish water, and distillation would be required, which would increase the cost of product water. As explained in Chapter 2, the desalting of sea water by reverse osmosis is being extensively researched but is still in the research and development stage.

Three processes were evaluated for use at Refugio: vapor compression distillation of sea water, and re-

Table 20. Chemical Composition of Water Supply and of Sea Water at Refugio State Beach

Constituents	ppm Existing Well	ppm Sea Water
Bicarbonate, HCO_3	634	140
Carbonates, CO_3	–	–
Chloride, Cl	307	18,980
Fluorides, F	–	–
Nitrate, NO_3	4	–
Nitrites, NO_2	–	–
Phosphate, PO_4	–	–
Sulfate, SO_4	840	2,600
Sulfides, S	–	–
Silica, SiO_2	24	–
Arsenic, As	–	–
Boron, B	–	–
Calcium, Ca	361	400
Copper, Cu	0.03	–
Iron, Fe	1.8	–
Magnesium, Mg	138	1,272
Manganese, Mn	–	–
Potassium, K	6	380
Selenium, Se	–	–
Sodium, Na	239	10,561
Hardness as $CaCO_3$	1,469	–
Total Dissolved Solids	1,915	33,600
pH	7.9	7.7
Conductivity (micromhos per cm)	2,710	–

– Not analyzed.

verse osmosis and electrodialysis treatment of brackish ground water. The results are shown in Table 21. Not included in the analysis is another possible alternative—the blending of desalted sea water with brackish ground water to produce usable supplies. Still another alternative to be considered is the treatment of sufficient water at Gaviota State Park to supply both Gaviota and Refugio. This will be discussed more fully in the following section of this chapter (under Gaviota).

Figure 30 is a flow diagram of the proposed desalting application, using reverse osmosis to treat brackish ground water at Refugio. The possible location of desalting facilities, along with other water supply facilities, is shown in Figure 31. The desalting facilities could be constructed in a wooded area near the existing water storage tanks. The pipeline for discharge of brines to the ocean would be buried and thus would not impair the landscape. If sea water were to be desalted, the desalting facilities could be located closer to the shore. The sea water intake could be adjacent to the discharge line and both could be hidden from view.

Brine could be disposed of by discharge into (1) an evaporation basin, or (2) the present disposal system, where waste water percolates into the ground through leach fields above the beach, or (3) the ocean. However, evaporation would be impractical because of both the limited area available and the low net evaporation rate. Disposal by percolation through a leach field above the beach would also be impractical, because the soil does not leach well, and the brines might seep into part of the beach area, or might possibly percolate into aquifers containing usable water supplies. Discharge into the ocean would be the most acceptable alternative. However, to protect the marine environment, the brines would have to be adequately diffused at the point of discharge.

In construction of the desalting facilities, special measures might be required to preserve the natural appearance of the beach. For example, a screen of

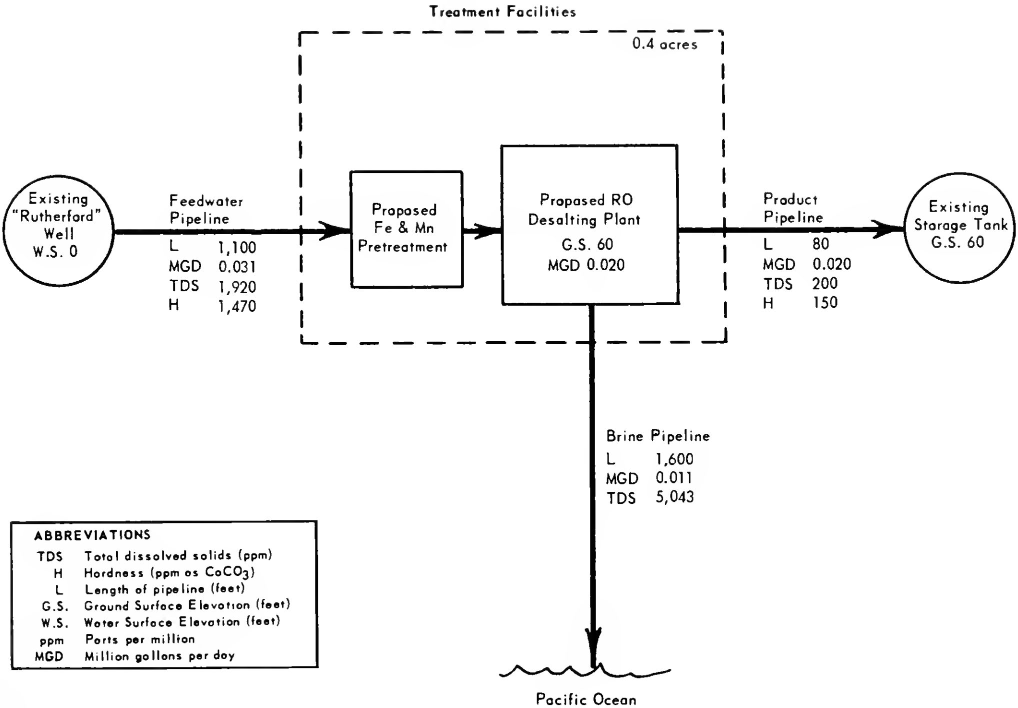


Figure 30. Schematic Diagram of Proposed Desalting Operation at Refugio State Beach

natural growth might be used to partially conceal the desalter. The desalter housing would muffle excessive noise, so that the serenity of the area would not be disturbed. Although installation of the brine pipeline would require trenching, this could be quickly filled and the natural appearance of the beach restored.

Benefits

The new plan for Refugio State Beach under development by the Department of Parks and Recreation includes improved facilities and new features for the convenience of visitors. Desalting could provide the good-quality water supplies that will be needed for drinking and cooking and for other uses, such as showering and laundering. The desalting plant and auxuliary facilities would also serve as an unusual sight-seeing feature. In this capacity, the plant could be used to demonstrate the role of desalting in the management of water supplies in keeping with careful preservation of the environment. Such a feature, open to public scrutiny, would serve as a model to demonstrate the desalting of sea water, or brackish ground water, along with concern for the environment in construction of the facilities, operation of the plant, and the disposal of brines.

Feasibility

Either reverse osmosis or electrodialysis could be used to desalt local ground water. Vapor compression distillation could be used to desalt sea water. However, as shown in Table 21, the cost of desalting sea water would be higher.

Tables 21 and 23 (see Gaviota State Park) show that the cost of desalting at Refugio ranges from two to three times that at Gaviota State Park. The tables also show that (1) the capacity of the proposed facility at Gaviota is 5 times that proposed for Refugio, and (2) the load factor at Gaviota is 90 percent compared with 50 percent at Refugio. This indicates that a combined facility to serve both Refugio and Gaviota, as discussed in the following section, may be the most feasible alternative. However, additional study would be required to evaluate a facility to serve both locations.

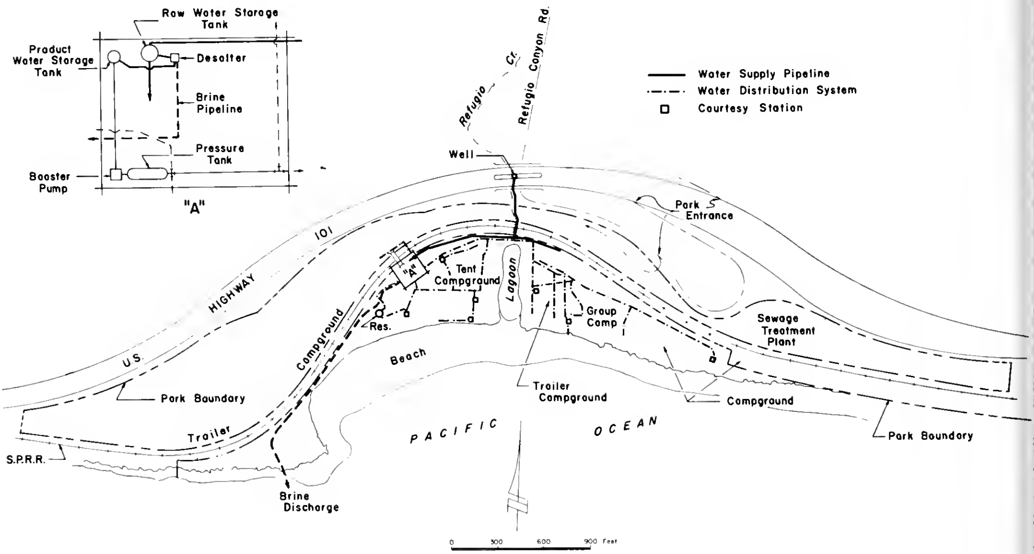


Figure 31. Location of Proposed Desalting Facilities at Refugio State Beach

Table 21. Refugio State Beach: Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 3,650,000 gallons
Peak daily requirements .... 20,000 gallons
Annual desalting plant load factor .... 50 percent

Output	Source of feedwater				
	Ground water				Sea water
	Process				
	Reverse Osmosis		Electrodialysis		Vapor Compression
	1	2	1	2	
Annual output (millions of gallons)					
Desalted	3.10	3.65	3.65	3.65	3.65
Raw	0.55	0	0	0	0
Total blended product	3.65	3.65	3.65	3.65	3.65
Peak daily output (millions of gallons)					
Desalted	0.017	0.020	0.020	0.020	0.020
Raw	0.003	0	0	0	0
Total blended product	0.020	0.020	0.020	0.020	0.020
Characteristics of blended product					
TDS (ppm)	500	195	500	195	10
hardness (ppm as $CaCO_3$)	384	150	384	150	8
Costs					
Capital costs ($1,000s)	41	48	57	57	101
Annual costs ($1,000s)					
Capital	2.9	3.3	4.0	4.0	6.9
Operations and maintenance	7.6	8.1	8.0	8.0	13.8
Replacement	0.3	0.4	0.4	0.4	0
Total	10.8	11.8	12.4	12.4	20.7
Cost of blended product per 1,000 gallons ($s)					
Capital	0.80	0.90	1.10	1.10	1.89
Operations and maintenance	2.08	2.22	2.19	2.19	3.78
Replacement	0.08	0.11	0.11	0.11	0
Total	2.96	3.23	3.40	3.40	5.67
Land requirement (acres)	0.4	0.4	0.3	0.3	0.4

[1] For degree of treatment required to reduce TDS to 500 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 150 ppm.

Gaviota State Park

Summary of Assessment for Gaviota State Park

	Quantity, mgd	*Quality, ppm of TDS*	*Desalting Cost, $ per 1,000 gals.*
Desalted Water	0.09	250	1.06
Raw (untreated) Water Used For Blending	0.01	2,650	
Total Blended Product	0.10	500	0.95
Capacity of Desalting Plant	0.09 mgd		
Annual Desalting Plant Load Factor	90 percent		

Data is for the lowest cost method of achieving the criteria desired by Gaviota State Park. Schematic drawing of the physical arrangements is shown in Figure 32, and data on alternative methods are shown in Table 23 and in Appendix A.

Gaviota State Park (Figure 2) is about 4 miles north of Refugio State Beach, the subject of the preceding section. As at Refugio, the California Department of Parks and Recreation is planning to improve the park facilities and construct extensive new accommodations. The present development area is near the beach along Gaviota Creek, a wide stream basin that drains most of the 2,800 acres in the park. Adjacent to the stream basin, the park extends from the beach up an incline to a gently sloping terrace, beyond which are low hills that finally merge into the steep hillsides that mark the park boundaries.

U. S. Highway 101 passes through the northeastern portion of the park and then turns south to Santa Barbara. At Gaviota, a traveler from the north would get his first glimpse of the ocean after a 60-mile journey through rolling hills.

The mild air and water temperatures are similar to those at Refugio, and Gaviota State Park is a popular year-round recreation area for picnicking, hiking, horseback riding, and camping. The park contains extensive hiking and equestrian trails through the hills, a fishing pier with boat-launching facilities extends into the ocean beyond the surf line, and the beach area is almost 2 miles long, except at high tide when it is reduced to about 600 feet. The new development plan includes several additional camping units and provisions for campers, trailers, and motor homes. When the proposed improvements are completed, the park will attract many more visitors.

Water Supply

Water for Gaviota State Park is obtained from a single shallow well. The water is brackish and very hard. No surface water is available to meet even a portion of the need nor could any be feasibly imported. However, additional good-quality water supplies —especially when the new park facilities have been completed—are essential. The Department of Parks and Recreation has investigated alternative local sources of water but has found none better than the existing park water supply. Therefore, they have recommended continued use of the existing well, even after the new developments have been completed.

The development plan includes two water systems: one for irrigation and waste disposal and another for drinking, cooking, and washing. The irrigation water would be untreated ground water, which would also be used to convey wastes in a sewage collection system to the proposed waste water treatment plant.

The Salt Problem

The quality of the present water supply is unsatisfactory for drinking, cooking, or washing. As shown in Table 22, the salt concentration in the ground water used at Gaviota includes an average TDS content of 2,650 ppm and hardness as $CaCO_3$ of more than 1,000 ppm. The average sulfate concentration is 480 ppm. The salt concentration of other ground water in the vicinity of the park is similar.

Desalting Application

Either brackish ground water or sea water is available for desalting at Gaviota. However, as mentioned in the preceding discussion of Refugio State Beach, the use of sea water would require distillation and increase the cost of product water.

Three desalting processes were evaluated for use at Gaviota: reverse osmosis and electrodialysis for treatment of brackish ground water and vapor compression distillation of sea water. The results of these analyses are shown in Table 23. As mentioned in the preceding section, another alternative to be considered is the blending of treated sea water with untreated ground water to produce sufficient water supplies.

Table 22. Chemical Composition of Water Supply and of Sea Water at Gaviota State Park

Constituents	ppm	
	Existing Well	*Sea Water*
Bicarbonate, HCO_3	360	140
Carbonates, CO_3	0	–
Chloride, Cl	700	18,980
Fluorides, F	0.5	–
Nitrate, NO_3	71	–
Nitrites, NO_2	–	–
Phosphate, PO_4	–	–
Sulfate, SO_4	480	2,600
Sulfides, S	–	–
Silica, SiO_2	–	–
Arsenic, As	–	–
Boron, B	3.3	–
Calcium, Ca	218	400
Copper, Cu	–	–
Iron, Fe	7	–
Magnesium, Mg	51	1,272
Manganese, Mn	0.77	–
Potassium, K	5	380
Selenium, Se	–	–
Sodium, Na	320	10,561
Hardness as $CaCO_3$	1,010	–
Total Dissolved Solids	2,650	33,600
pH	8.0	7.7
Conductivity (micromhos per cm)	3,600	–

– Not analyzed.

The third alternative mentioned in the preceding section, i.e., the desalting of sufficient water at Gaviota State Park to supply both Gaviota and Refugio, would require increasing the desalting capacity at Gaviota by 20 percent and transporting treated water to Refugio. However, as shown in Tables 23 and 21, the estimated unit cost of treating water by reverse osmosis at Gaviota is only $0.95 per 1,000 gallons of product water, compared with $3.23 per 1,000 gallons at Refugio. This higher treatment cost results from the higher hardness content of the water at Refugio (Tables 20 and 22), and the higher capacity and load factor of the desalting facilities at Gaviota (Tables 21 and 23). The estimated cost of transporting treated water to Refugio is about $1.25 per 1,000 gallons.

Figure 32 is a schematic diagram of the proposed desalting application at Gaviota, using reverse osmosis to treat brackish ground water. The desalting facilities and other water supply facilities are shown in Figure 33. The possible location for the desalting plant on the terrace upslope from the beach overlooks the present park facilities along Gaviota Creek. As shown in Figure 33, the desalter would adjoin the proposed park maintenance building a short distance from the present ground-level water storage reservoir.

Consideration of environmental impact from the desalting facilities would receive special attention at Gaviota. At its proposed location, the desalting plant would not be visible from the present park area, but it could be seen from a part of the proposed new development. However, trees and shrubs could be planted to partially conceal the desalting facilities.

Buried pipelines would be used to convey water from the well to the desalting plant and to convey brines from the desalter to the ocean. At the edge of the beach, the brine pipeline could be suspended beneath the deck of the fishing pier and thus would be concealed as it extends out into the ocean. Because the brines would contain higher proportions of certain minerals that ordinarily occur in sea water, they would have to be adequately diffused at the point of discharge to protect the marine environment.

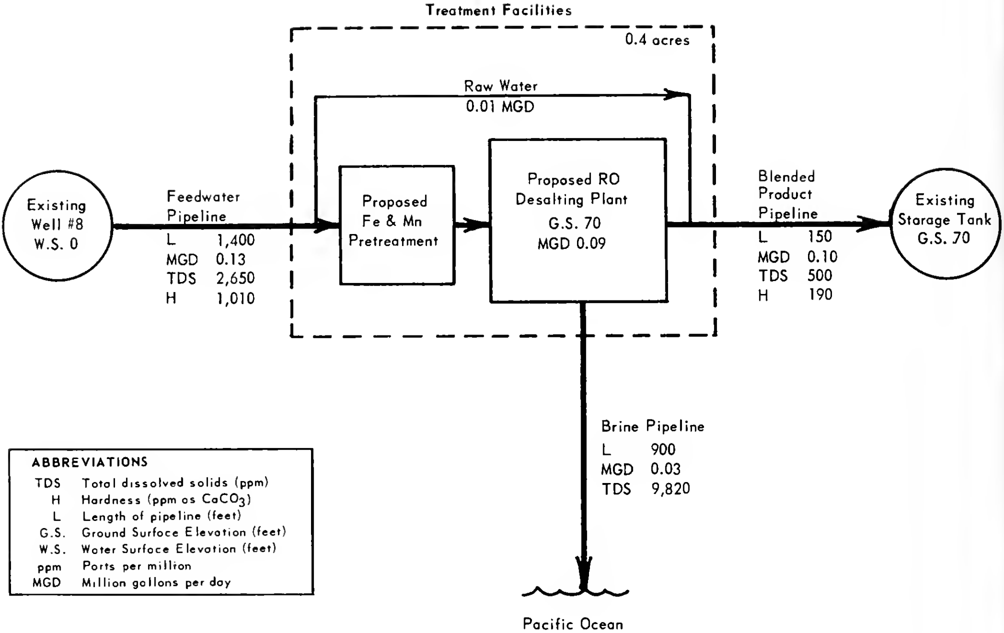


Figure 32. Schematic Diagram of Proposed Desalting Operation at Gaviota State Park

As mentioned in the preceding discussion of Refugio, alternative methods of brine disposal include evaporation or discharge into the proposed sewage collection system. However, the former would be impractical because of both the low net evaporation rate along the coast and the large acreage required for an evaporation basin. Disposal into the sewage treatment system would also result in problems because, after discharge from the treatment plant, the brines might seep into the park area or percolate into aquifers containing usable water supplies.

The development of the proposed new park facilities will require increasing the water yield of the existing well, constructing additional water storage facilities, and installing several miles of buried pipelines. If desalting facilities are also constructed, the adverse environmental impact would be minimized if all improvements could be made at the same time.

Benefits

Desalting could provide the good-quality water supply that will be needed at Gaviota State Park for drinking, cooking, showering, laundering, etc. And, as suggested at Refugio State Beach, the desalting plant could also serve as a public attraction to demonstrate the role of desalting in the management of water supplies in keeping with careful preservation of the environment.

Feasibility

Either reverse osmosis or electrodialysis could be used to desalt the local ground water. Vapor compression distillation could be used to desalt sea water. However, as shown in Table 23, the cost of desalting sea water would be about 2.5 times greater.

Tables 21 and 23 show that the cost of desalting at Gaviota would be considerably lower than that at Refugio. The tables also show that (1) the capacity of the proposed facility at Gaviota is 5 times that proposed for Refugio, and (2) the load factor is 90 percent, compared with only 50 percent at Refugio. Therefore, further study may indicate that a combined facility to serve both Gaviota State Park and Refugio State Beach would be the most feasible alternative.

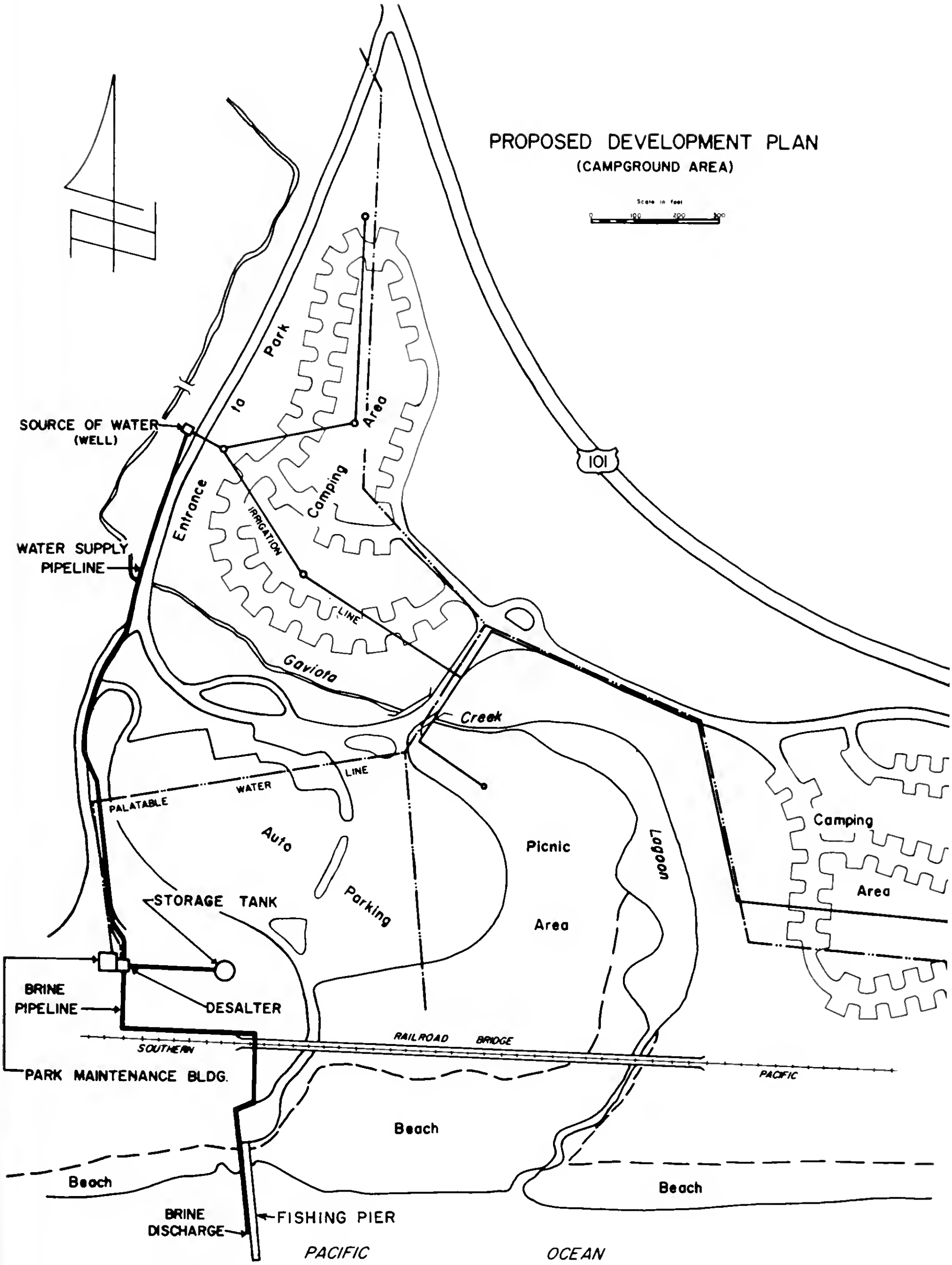


Figure 33. Location of Proposed Desalting Facilities at Gaviota State Park

Table 23. Gaviota State Park: Estimated Output of Desalter, Costs of Desalting, and Land Requirements

Annual water requirements .... 32,900,000 gallons
Peak daily requirements .... 100,000 gallons
Annual desalting plant load factor .... 90 percent

Output	Source of feedwater				
	Ground water				Sea water
	Reverse Osmosis		Electrodialysis		Vapor Compression
	1/	2/	1/	2/	
Annual output (millions of gallons)					
Desalted	29.6	32.9	32.9	32.9	32.9
Raw	3.3	0	0	0	0
Total blended product	32.9	32.9	32.9	32.9	32.9
Peak daily output (millions of gallons)					
Desalted	0.09	0.10	0.10	0.10	0.10
Raw	0.01	0	0	0	0
Total blended product	0.10	0.10	0.10	0.10	0.10
Characteristics of blended product					
TDS (ppm)	500	262	500	262	10
hardness (ppm as $CaCO_3$)	191	100	191	100	4
Costs					
Capital costs ($1,000s)	134	146	232	232	389
Annual costs ($1,000s)					
Capital	9.2	10.0	15.9	15.9	26.6
Operations and maintenance	19.1	20.4	21.7	21.7	53.0
Replacement	3.0	3.3	3.2	3.2	0
Total	31.3	33.7	40.8	40.8	79.6
Cost of blended product per 1,000 gallons ($s)					
Capital	0.28	0.30	0.48	0.48	0.81
Operations and maintenance	0.58	0.62	0.66	0.66	1.61
Replacement	0.09	0.10	0.10	0.10	0
Total	0.95	1.02	1.24	1.24	2.42
Land requirement (acres)	0.4	0.4	0.3	0.3	0.4

[1] For degree of treatment required to reduce TDS to 500 ppm.
[2] For degree of treatment required to reduce hardness (as $CaCO_3$) to 100 ppm.

APPENDIX A

COST ESTIMATES
AND
POSSIBLE SOURCES OF FINANCING

APPENDIX A
COST ESTIMATES AND POSSIBLE SOURCES OF FINANCING

Cost Estimates

The cost estimates provided in Chapter 4 and in this appendix were not intended for use in making final decisions or as the basis for determining either funding requirements or repayment negotiations. If the estimated costs in this bulletin indicate that desalting may be feasible in a given community, more detailed estimates and exact cost data from manufacturers will be needed to establish final costs.

The costs were estimated on the basis of (1) facilities that would be large enough to meet present or near-future water demands, and (2) 1973 prices. Cost estimates for additional facilities that might be needed at some future time. e.g., 1980, 1990, 2000, etc., to meet long-term water demands, would be less accurate because of (1) the uncertainty of future water demands, and (2) the expected escalation of both construction costs and operation and maintenance costs.

The capital cost of facilities includes the cost of constructing facilities for (1) pretreatment of feedwater, (2) desalting, and (3) disposal of brine, along with the cost of any additional facilities needed. Annual costs include the costs of operation and maintenance, and replacement costs. The unit costs per 1,000 gallons of product water are shown for each of the five desalting processes considered in the study. The costs for each community are presented in Chapter 4 and in more detail in Tables A-1, A-2, and A-3 in this appendix.

Table A-4 presents estimates of land required, the costs of which are a part of Table A-1. Table A-5 shows the estimated requirements for electrical energy, the costs of which are included in Tables A-2 and A-3.

The cost estimate data used for this study were obtained from the Office of Saline Water publication "Desalting Handbook for Planners", input from vendors of desalting equipment, and input from local entities in the various communities. The desalting handbook contains cost data for the five desalting processes considered in this study; however, data on the small-capacity plants considered for certain communities were not available. In such cases, equipment vendors provided cost data, which were used to develop capital costs. Costs of rights of way and land were provided by representatives of the various communities.

The base for all costs is the summer of 1973. The cost data in the desalting handbook were updated with cost indexes developed by "Engineering News Record", the Bureau of Reclamation, and the Bureau of Labor Statistics.

Each cost estimate is based on the following assumptions: (1) the life time of the desalting facilities will be 30 years; (2) the interest rate for municipal financing will be 5.5 percent; (3) there will be no charges for taxes or insurance; and (4) all capital costs, except for the cost of land, will be depreciated over 30 years. The estimated cost of electricity for each desalting plant was based on the 1973 electric utility schedules used in each area.

The estimated costs are also based on a feedwater temperature of 77°F. If, in a given community, the temperature of the feedwater were significantly lower, the estimates would have to be revised, because the efficiency of some desalting processes would also be lower.

As explained in Chapter 4, most of the communities requested that their water supplies be desalted to levels of (1) 500 ppm TDS and (2) 100 ppm of hardness as $CaCO_3$. Accordingly, the initial estimates were based on attainment of a product-water concentration of those levels.

Two cost estimates were determined for desalting by reverse osmosis and electrodialysis, because neither of these processes could be used, at a given degree of treatment, to attain the desired levels of both TDS and hardness. For example, in one community, the degree of treatment required to reduce TDS to 500 ppm by reverse osmosis would reduce hardness to only 204 ppm. Conversely, the greater degree of treatment required to reduce hardness to 100 ppm would also reduce TDS to 245 ppm, a lower concentration than required for acceptable domestic supplies, but at an increased cost of $0.18 per 1,000 gallons of product water.

The annual plant load factor shown in the cost tables in Chapter 4 also significantly affects the cost of product water. The load factor is the proportion of the annual design capacity that would actually be produced by the desalter. Except for the costs of energy and brine disposal, the operating cost of a plant operated at less than full capacity will not be significantly)lower than that of a plant operated at full capacity.

The unit cost of desalted water is also affected by the size (capacity) of the desalter. In most cases, for a given desalting process, the smaller the capacity of the plant, the higher the unit cost of product water.

Table A-1, Capital Costs ($1,000s)

Based on TDS of product water meeting client's requirements. Hardness of product water may not satisfy client's requirements. (Reverse osmosis, electrodialysis)

TDS and hardness of product water meet client's requirements. (Ion exchange)

Item	Process	Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Refugio	Gaviota
Construction costs	REVERSE OSMOSIS									
Desalting plant		390	163	125	35	243	60	144	25	82
Brine disposal		41	56	51	44	31	8	49	0	0
Pretreatment		0	9	0	0	0	3	6	1	9
General site development		87	43	35	11	59	19	40	8	25
Total construction costs		518	271	211	90	333	90	239	34	110
Interest during construction		7	4	3	1	5	1	3	0	2
Start-up costs		5	2	2	1	3	1	2	1	2
Owner's general expense		67	35	30	14	43	14	33	5	17
Land		2	39	3	4	0	1	3	0	0
Working capital		10	5	4	2	6	2	4	1	3
Total capital costs		609	356	253	111	390	109	284	41	134
Construction costs	ELECTRODIALYSIS									
Desalting plant		495	362	316	63	362	83	327	36	166
Brine disposal		94	150	139	44	93	8	47	0	0
Pretreatment		0	9	0	0	0	3	6	1	3
General site development		121	74	66	11	100	22	50	10	27
Total construction costs		710	595	521	118	555	116	430	47	196
Interest during construction		14	8	7	2	9	2	6	1	3
Start-up costs		5	3	3	1	4	1	2	1	2
Owner's general expense		85	77	68	18	72	17	56	7	27
Land		5	91	2	3	0	1	2	0	0
Working capital		11	7	6	2	7	2	5	1	4
Total capital costs		830	781	607	144	647	139	501	57	232
Construction costs	ION EXCHANGE									
Desalting plant		407	211	180		367	131	181		
Brine disposal		329	299	203		623	29	232		
Pretreatment		0	0	0		0	0	0		
General site development		87	65	57		104	25	43		
Total construction costs		823	575	440		1,094	185	456		
Interest during construction		11	8	6		18	3	6		
Start-up costs		5	4	3		6	1	3		
Owner's general expense		99	69	53		131	26	59		
Land		16	186	5		0	4	11		
Working capital		10	7	7		12	3	6		
Total capital costs		964	849	514		1,261	222	541		

Based on TDS and hardness of product water meeting client's requirements. If client stated no hardness requirement, 100 ppm as $CaCO_3$ is assumed. (Reverse osmosis, electrodialysis)

TDS and hardness very low, well within client's requirements. (Distillation)

Item	Process	Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Marin	Refugio	Gaviota
Construction costs	REVERSE OSMOSIS										
Desalting plant		420	306	276	35	388	86	178		28	91
Brine disposal		45	131	129	48	51	13	64		0	0
Pretreatment		0	9	0	0	0	3	6		1	3
General site development		89	74	66	11	86	27	47		10	27
Total construction costs		554	520	471	94	525	129	295		39	121
Interest during construction		9	7	6	1	7	2	4		1	2
Start-up costs		5	4	4	1	4	1	2		1	2
Owner's general expense		72	68	61	14	63	18	38		6	18
Land		2	84	3	3	0	2	3		0	0
Working capital		10	8	8	2	8	3	5		1	3
Total capital costs		652	691	553	115	607	155	347		48	146
Construction costs	ELECTRODIALYSIS										
Desalting plant		495	564	483	63	568	166	327		36	166
Brine disposal		94	150	139	48	108	13	64		0	0
Pretreatment		0	9	0	0	0	3	6		1	3
General site development		121	74	66	11	104	27	50		10	27
Total construction costs		710	797	688	122	780	209	447		47	196
Interest during construction		14	11	9	2	13	3	6		1	3
Start-up costs		5	3	3	1	4	1	2		1	2
Owner's general expense		85	96	83	18	94	29	58		7	27
Land		5	91	2	2	0	2	3		0	0
Working capital		11	7	6	2	8	3	5		1	4
Total capital costs		830	1,005	791	148	899	247	521		57	232
Construction costs	DISTILLATION										
Desalting plant									4,687	74	299
Brine disposal									0	0	0
Pretreatment									0	0	0
General site development									272	10	27
Total construction costs									4,959	84	326
Interest during construction									245	1	4
Start-up costs									88	1	4
Owner's general expense									496	13	46
Land									0	0	0
Working capital									176	2	9
Total capital costs									5,964	101	389

Table A-2, Annual Costs ($1,000s)

Community		Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Refugio	Gaviota
Item	Process	Based on TDS of product water meeting client's requirements. Hardness of product water may not satisfy client's requirements.								
Capital	REVERSE OSMOSIS	41.8	23.9	17.3	7.6	26.7	7.5	19.5	2.9	9.2
Operation & Maintenance	REVERSE OSMOSIS	58.0	29.3	25.1	9.3	37.4	12.3	24.4	7.6	19.1
Replacement	REVERSE OSMOSIS	9.9	4.9	4.1	0.4	5.3	0.4	3.7	0.3	3.0
Total	REVERSE OSMOSIS	109.7	58.1	46.5	17.3	69.4	20.2	47.6	10.8	31.3
Capital	ELECTRODIALYSIS	56.9	52.4	41.6	9.9	44.4	9.6	34.4	4.0	15.9
Operation & Maintenance	ELECTRODIALYSIS	63.2	39.3	36.1	10.1	44.3	12.9	28.1	8.0	21.7
Replacement	ELECTRODIALYSIS	9.5	4.8	3.2	0.8	4.8	1.6	6.3	0.4	3.2
Total	ELECTRODIALYSIS	129.6	96.5	80.9	20.8	93.5	24.1	68.8	12.4	40.8
		TDS and hardness of product water meet client's requirements.								
Capital	ION EXCHANGE	65.9	55.7	35.2		86.6	15.2	37.0		
Operation & Maintenance	ION EXCHANGE	57.4	42.7	40.4		73.0	15.0	33.3		
Replacement	ION EXCHANGE	12.2	6.3	5.4		11.0	3.9	5.4		
Total	ION EXCHANGE	135.5	104.7	81.0		170.6	34.1	75.7		

Community		Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Marin	Refugio	Gaviota
Item	Process	Based on TDS and hardness of product water meeting client's requirements. If client stated no hardness requirement, 100 ppm as $CaCO_3$ is assumed.									
Capital	REVERSE OSMOSIS	44.7	46.3	37.9	7.9	41.6	10.6	23.7		3.3	10.0
Operation & Maintenance	REVERSE OSMOSIS	60.5	48.1	45.4	9.4	49.7	15.5	28.8		8.1	20.4
Replacement	REVERSE OSMOSIS	10.6	11.0	11.0	0.4	9.2	0.7	4.9		0.4	3.3
Total	REVERSE OSMOSIS	115.8	105.4	94.3	17.7	100.5	26.8	57.4		11.8	33.7
Capital	ELECTRODIALYSIS	56.9	67.8	54.3	10.1	61.7	16.9	35.7		4.0	15.9
Operation & Maintenance	ELECTRODIALYSIS	63.2	41.3	37.7	10.2	47.9	15.8	28.2		8.0	21.7
Replacement	ELECTRODIALYSIS	9.5	11.0	9.5	0.8	12.4	3.2	6.3		0.4	3.2
Total	ELECTRODIALYSIS	129.6	120.1	101.5	21.1	122.0	35.9	70.2		12.4	40.8
		TDS and hardness of product water very low, well within client's requirements.									
Capital	DISTILLATION								407.7	6.9	26.6
Operation & Maintenance	DISTILLATION								1,055.2	13.8	53.0
Replacement	DISTILLATION								0	0	0
Total	DISTILLATION								1,462.9	20.7	79.6

Table A-3, Operation and Maintenance Costs ($1,000s)

Item	Process	Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Refugio	Gaviota
		Based on TDS of product water meeting client's requirements. Hardness of product water may not satisfy client's requirements.								
Desalting Plant	REVERSE OSMOSIS	27.0	16.9	14.7	6.8	20.9	10.0	15.7	6.0	11.8
Pretreatment		0	0.9	0	0	0	0.3	0.6	0.1	0.9
Chemicals		5.2	2.6	2.2	0.2	2.8	0.2	2.0	0.2	1.5
Electricity		25.5	8.5	7.8	2.0	13.5	1.7	5.7	1.3	4.9
Ponds		0.3	0.4	0.4	0.3	0.2	0.1	0.4	0	0
Total		58.0	29.3	25.1	9.3	37.4	12.3	24.4	7.6	19.1
Desalting Plant	ELECTRODIALYSIS	33.8	24.6	23.0	7.0	29.1	10.7	19.8	6.5	13.2
Pretreatment		0	0.9	0	0	0	0.3	0.6	0.1	0.9
Chemicals		8.6	5.8	5.7	0.2	6.2	0.3	2.8	0.2	1.7
Electricity		20.1	6.9	6.4	2.6	8.3	1.5	4.5	1.2	5.9
Ponds		0.7	1.1	1.0	0.3	0.7	0.1	0.4	0	0
Total		63.2	39.3	36.1	10.1	44.3	12.9	28.1	8.0	21.7
		TDS and hardness of product water meet client's requirements.								
Desalting Plant	ION EXCHANGE	27.2	21.6	19.9		30.0	12.3	17.1		
Pretreatment		0	0	0		0	0	0		
Chemicals		15.0	15.8	15.0		32.3	1.6	13.2		
Electricity		12.7	3.1	4.0		5.9	0.9	1.3		
Fuel		0	0	0		0	0	0		
Ponds		2.5	2.2	1.5		4.8	0.2	1.7		
Intake and Outfall		0	0	0		0	0	0		
Total		57.4	42.7	40.4		73.0	15.0	33.3		

Item	Process	Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Marin	Refugio	Gaviota
		Based on TDS and hardness of product water meeting client's requirements. If client stated no hardness requirement, 100 ppm as $CaCO_3$ is assumed.									
Desalting Plant	REVERSE OSMOSIS	28.2	24.1	22.6	6.8	27.0	12.4	17.9		6.4	12.4
Pretreatment		0	0.9	0	0	0	0.3	0.6		0.1	0.9
Chemicals		5.5	5.8	5.7	0.2	4.8	0.4	2.6		0.2	1.7
Electricity		26.5	16.3	16.1	2.0	17.5	2.3	7.2		1.4	5.4
Ponds		0.3	1.0	1.0	0.4	0.4	0.1	0.5		0	0
Total		60.5	48.1	45.4	9.4	49.7	15.5	28.8		8.1	20.4
Desalting Plant	ELECTRODIALYSIS	33.8	26.6	24.6	7.0	32.0	13.2	19.8		6.5	13.2
Pretreatment		0	0.9	0	0	0	0.3	0.6		0.1	0.9
Chemicals		8.6	5.8	5.7	0.2	6.5	0.4	2.8		0.2	1.7
Electricity		20.1	6.9	6.4	2.6	8.6	1.8	4.5		1.2	5.9
Ponds		0.7	1.1	1.0	0.4	0.8	0.1	0.5		0	0
Total		63.2	41.3	37.7	10.2	47.9	15.8	28.2		8.0	21.7
		TDS and hardness very low, well within client's requirements.									
Desalting Plant	DISTILLATION								308.1	6.8	14.5
Pretreatment									0	0	0
Chemicals									18.0	0.1	0.7
Electricity									78.0	6.9	37.8
Fuel									632.4	0	0
Ponds									0	0	0
Intake and Outfall									18.7	0	0
Total									1,055.2	13.8	53.0

Table A-4, Land Requirements (acres)

Based on TDS of product water meeting client's requirements. Hardness of product water may not satisfy client's requirements.

Item	Process	Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Refugio	Gaviota
Plant	REVERSE OSMOSIS	0.8	0.7	0.6	0.4	0.7	0.5	0.6	0.4	0.4
Ponds		4.3	5.8	5.3	4.6	3.2	0.8	5.1	0	0
Roads		0.6	0.9	0.8	0.7	0.5	0.1	0.8	0	0
Total		5.7	7.4	6.7	5.7	4.4	1.4	6.5	0.4	0.4
Plant	ELECTRODIALYSIS	0.4	0.3	0.4	0.3	0.5	0.3	0.4	0.3	0.3
Ponds		9.7	15.5	14.4	4.6	9.6	0.8	4.9	0	0
Roads		1.5	2.3	2.2	0.7	1.4	0.1	0.7	0	0
Total		11.6	18.1	17.0	5.6	11.5	1.2	6.0	0.3	0.3
		TDS and hardness of product water meet client's requirements.								
Plant	ION EXCHANGE	1.0	0.9	0.9		1.0	0.8	0.8		
Ponds		34.1	31.0	21.0		64.6	3.0	24.0		
Roads		5.1	4.7	3.2		9.7	0.5	3.6		
Total		40.2	36.6	25.1		75.3	4.3	28.4		

Based on TDS and hardness of product water meeting client's requirements. If client stated no hardness requirement, 100 ppm as $CaCO_3$ is assumed.

Item	Process	Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Marin	Refugio	Gaviota
Plant	REVERSE OSMOSIS	0.8	0.7	0.6	0.4	0.7	0.5	0.6		0.4	0.4
Ponds		4.7	13.6	13.4	5.0	5.3	1.3	6.6		0	0
Roads		0.7	2.0	2.0	0.8	0.8	0.2	1.0		0	0
Total		6.2	16.3	16.0	6.2	6.8	2.0	8.2		0.4	0.4
Plant	ELECTRODIALYSIS	0.4	0.3	0.4	0.3	0.5	0.3	0.4		0.3	0.3
Ponds		9.7	15.5	14.4	5.0	11.2	1.3	6.6		0	0
Roads		1.5	2.3	2.2	0.8	1.7	0.2	1.0		0	0
Total		11.6	18.1	17.0	6.1	13.4	1.8	8.0		0.3	0.3
		TDS and hardness of product water very low, well within client's requirements.									
Plant	DISTILLATION								1.8	0.4	0.4
Ponds									0	0	0
Roads									0	0	0
Total									1.8	0.4	0.4

Table A-5, Electrical Energy Requirements (megawatthours per year) and Demand (kilowatts)

Based on TDS of product water meeting client's requirements. Hardness of product water may not satisfy client's requirements.

Item	Process	Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Refugio	Gaviota
Electricity per year	REVERSE OSMOSIS	1,537	551	523	57	672	53	403	35	329
Electricity per month		128.1	45.9	43.6	4.7	56.0	4.4	33.6	2.9	27.4
Demand		388	98	79	14	179	32	81	7	42
Electricity per year	ELECTRO-DIALYSIS	1,173	376	404	93	463	44	305	34	395
Electricity per month		97.7	31.3	33.7	7.7	38.6	3.7	25.4	2.8	33.0
Demand		296	70	61	22	123	26	61	7	50
		TDS and hardness of product water meet client's requirements.								
Electricity per year	ION EXCHANGE	646	132	209		302	20	66		
Electricity per month		53.8	11.0	17.4		25.2	1.7	5.5		
Demand		163	24	32		81	12	13		

Based on TDS and hardness of product water meeting client's requirements. If client stated no hardness requirement, 100 ppm as $CaCO_3$ is assumed.

Item	Process	Boron	Buellton	Greenfield	Old Cuyama	New Cuyama	Havasu	Winterhaven	Marin	Refugio	Gaviota
Electricity per year	REVERSE OSMOSIS	1,604	1,164	1,216	57	1,065	83	529		41	362
Electricity per month		133.7	97.0	101.3	4.7	88.7	6.9	44.1		3.4	30.2
Demand		405	207	184	14	284	49	106		9	46
Electricity per year	ELECTRO-DIALYSIS	1,173	376	404	93	482	58	306		34	396
Electricity per month		97.7	31.3	33.7	7.7	40.2	4.8	25.3		2.8	33.0
Demand		296	70	61	22	129	35	61		7	50
		TDS and hardness very low, well within client's requirements.									
Electricity per year	DISTILLATION								6,121	345	3,101
Electricity per month									510.1	28.8	258.4
Demand									1,040	78	390

Financing

Financial assistance for the construction of desalting facilities may be available under certain federal and state programs. Local financing might also be obtained through the sale of bonds or through a loan from a private financial institution. At the present time, funds for certain authorized federal programs have not been appropriated, and funds may not be available even to qualified recipients.

Both the federal and state programs have been established to assist the following organizations and agencies: county, state, federal, and private agencies, Indian tribes, and nonprofit organizations.

Federal Programs

Each of the federal financial aid programs described in the following paragraphs has been established to help finance improvements in water supply facilities.

1. Farmer Home Administration (Department of Agriculture) (7 USC 1926). This program provides loans, at an interest rate of not more than 5 percent over a repayment period of not more than 40 years, to public or quasi-public bodies or nonprofit corporations, for the purpose of installing, improving, or expanding water and waste-water disposal systems in rural communities of not more than 10,000 population, except for purposes of business and industrial loans and grants, in which case such aid could be made to areas of up to 50,000 inhabitants.

2. Public Facility Loans (Department of Housing and Urban Development) (42 USC 1492). This program assists in financing essential public works or facilities by purchasing securities issued to finance specific projects in cases where loans cannot otherwise be obtained on reasonable terms.

3. Water and Sewer Facilities Grant Program (Department of Housing and Urban Development) (38 USC 1804(e) and 12 USC 1735f). This program provides grants of a percent of the land and construction costs of new water and sewer projects, or for enlarging or improving existing facilities.

4. Economic Development Administration (Department of Commerce). (42 USC 3131). This program was established to assist with financing of public works and development facilities, including water and sewer lines, and water and waste water treatment plants. A goal of this program is to alleviate unemployment and increase median family income in economically distressed areas.

State Programs

Both state financial aid programs are adminstered by the California Department of Water Resources.

1. Davis-Grunsky Act (Water Code Section 12880, et. seq.). This program provides in part for financial assistance to public agencies for the construction of water projects to meet local requirements in which there is statewide interest by making grants or loans. The word *project* here means any dam, reservoir, or other construction or improvement by a public agency for the diversion, storage, or distribution of water primarily for domestic, municipal, agricultural, industrial, recreation, fish and wildlife enhancement, flood control, or power production purposes. The loan applicant must show that the proposed project is economically feasible and that the agency cannot reasonably finance the project from other sources. The loans must be repaid with an interest rate of 2.5 percent per annum. Funds authorized for the program under this act are practically committed.

Numerous public agencies in California have received grants or loans through this program; however, no assistance has yet been provided for construction of desalting facilities.

A bill is being considered by the California Legislature, AB 3431— "California Safe Drinking Water Bond Act of 1974", that would provide financial assistance in treatment of water supplies.

2. Saline Water Conversion Facilities Construction (Cobey-Porter Saline Water Conversion Law, Water Code Section 12945 et. seq.). This program assists county, state, federal, or local agencies, or public or private corporations, with the financing, construction, and operation of saline water conversion facilities. Funds disbursed under this program must be authorized by the California Legislature, and, unless otherwise designated by the Legislature, all funds must be repaid.

APPENDIX B

PRETREATMENT, POSTTREATMENT, STORAGE, AND DISPOSAL OF BRINES

APPENDIX B
PRETREATMENT, POSTTREATMENT, STORAGE, AND DISPOSAL OF BRINES

Pretreatment of Feedwater

Sources

The feedwater may be ground water, surface water, or sea water. The design criteria for a given desalting facility are based on, among other things, certain water quality conditions, such as TDS, hardness, acidity, and temperature. If the actual quality of the feedwater varies greatly from the preestablished criteria, operation of the desalting facilities may be unsatisfactory, the lifetime of the facilities may be shortened, and the product water may be unsatisfactory.

Therefore, a dependable source of feedwater with predictable characteristics is essential to proper operation of the desalting plant. The supply must be relatively continuous and free of sediments and colloidal materials that would clog membranes or foul resins.

Treatment

Feedwater must be pretreated when it contains substances that would impair operation of the desalting facilities. Such substances include suspended organics, such as moss, algae, bacteria, etc., which are frequently found in surface water. Brackish ground water often contains excessive gases, calcium, and sulfate.

The efficiency of distillation may be reduced by dissolved gases, such as carbon dioxide and oxygen. Membranes used in both electrodialysis and reverse osmosis are easily fouled and clogged by algae, slimes, and suspended solids. The resins used in ion exchange are subject to clogging by dissolved organics. Some reverse osmosis membranes are particularly affected by bacteria, which tend to deteriorate the membranes.

Specific treatment commonly used to correct these conditions includes:

- Coagulation, followed by sand or diatomaceous-earth filtration to remove suspended organic and inorganic materials, such as algae, bacteria, silt, etc.
- Activated carbon adsorption to remove dissolved organic materials.
- Lime soda softening to remove calcium, magnesium, iron, and manganese.
- Ion-exchange softening to remove calcium and manganese.
- Deaeration to remove excessive gases.

Postreatment of Desalted Water

After desalting, product water will usually require treatment before it can be distributed. Unless the product water is blended with other water supplies, buffering is required after distillation, because the product water is very active and could cause corrosion of concrete and iron in water distribution systems. Buffering can be accomplished by exposure to calcium carbonate or by blending with other water supplies.

After desalting by reverse osmosis, where feedwater has been acidified to prevent precipitation of calcium carbonate on membranes, the product water may require treatment to reduce the acidity. All desalting processes must be followed by chlorination of the product water.

Storage

To maintain a continuous supply of desalted water, some storage of product water will usually be required. For instance, there will be occasional short periods when the desalting facilities will be out of production for maintenance. A temporary change from desalted water to mineralized feedwater, which might occur if storage were not available, would be unacceptable to most water users. However, in most communities, some means of storage, e.g., reservoirs, tanks, is already available.

Blending of desalted water and feedwater might be used to extend the benefits of desalting. For instance, at small additional cost, feedwater could be desalted to TDS concentrations significantly lower than required for use in a community. This treated water could then be blended with untreated water to produce a product with an acceptable TDS or hardness content.

Such a system would enable the desalting of less feedwater to produce acceptable product water. Therefore, the cost of providing desalted water by blending might be less expensive than desalting the entire supply of feedwater. The feasibility of blending depends on the desalting process used and on the TDS concentration of both the feedwater and the product water.

Disposal of Brines

Regardless of the process used for desalting, an acceptable method of brine disposal must be provided. The four most common methods are:

1. Solar evaporation from a surface basin.
2. Discharge into a municipal waste water system.
3. Injection into deep aquifers.
4. Discharge into saline water, such as the ocean.

For most of the communities considered in this study disposal by evaporation would be the most feasible method. In communities where brines might be discharged into the ocean or into San Francisco Bay, discharge requirements for each site would be requested from the California Regional Water Quality Control Board with jurisdiction for setting such requirements.

Solar evaporation

Solar evaporation requires a large area of land so that the average annual evaporation from the basin water surface will dispose of the annual amount of brine discharged into the basin. The basin should be located so that any downwind drifting of salt will not cause damage.

Care must also be exercised to prevent seepage of brine into usable ground water. When brine is to be discharged on land overlying or adjacent to usable water, state policy requires that artificial barriers be constructed to provide both vertical and lateral confinement. In all cases, protection against both overflow from within and innundation from water outside the basin must be provided. For each evaporation basin considered in this study, artificial barriers would be used to control vertical and lateral movement of brines.

Where possible, evaporation basins should be located to enable gravity flow of brine from the desalting plant. To minimize conveyance costs, the basin should be located as near the desalter as is feasible. Environmental conditions, suitable terrain, and land costs may also be significant factors governing selection of a site. In cases where wind drift of brines would not be a problem, parks or recreation facilities might be constructed in areas adjacent to the basin.

The size of a basin will be determined by the size of the surface area required to evaporate the annual inflow of brine. The shape of a basin may be determined by the shape of the surrounding terrain. A rectangular basin simplifies maintenance and the periodic removal of accumulated salts.

The depth of water in the ponds will depend on the rate of inflow of brines requiring disposal and the evaporation rate. Exterior embankments must have sufficient freeboard to confine the maximum quantity of brine with some allowance for accumulated salts on the basin floor. Sufficient additional freeboard must be provided to contain (1) precipitation on the basin, (2) increased depths of water in emergencies, and (3) wave wash caused by wind. Cells within the basin can minimize the freeboard required to minimize wave wash.

Linings of various types can also be installed to help confine the brines. Buried plastic !or rubber membranes provide an effective barrier. The membrane is covered by a foot or more of soil to anchor it and protect against puncture.

The rate of evaporation above the basin can be increased by more efficient operation. For example, the color of both the bottom of the basin and the brine can effect the evaporation rate; the darker the color, the higher the evaporation rate. If algae are permitted to accumulate in the water, the evaporation rate will be decreased. The air above the basin becomes quickly saturated with water vapor and must be continuously moved and replaced with drier air. Because the winds prevailing above the basin afford natural movement of air, buildings, land formations, or vegetation that would act as windbreaks would also decrease the evaporation rate.

The discharge of brine through sprinklers has also been used to increase the rate of evaporation and, in commercial operations, to recover certain salts. However, large quantities of energy are required to pump the brine through a sprinkler system. Another problem is the constant plugging of sprinkler nozzles caused by the high salt content of the brine.

Evaporation basins could also be constructed in stages, if a staged increase in desalting capacity were planned. And, finally, if the desalting operation were terminated, the basin could be reclaimed by installing a plastic sheet over the accumulated salts and covering the sheet with a few feet of soil.

Discharge into a Municipal Waste Water Disposal System

This appears to be a simple means of brine disposal. On the other hand, ordinary waste water treatment facilities will not remove significant amounts of salt, and this means of disposal might merely transfer the problem from one site to another. Furthermore, such discharges may be prohibited by State regulations, particularly in areas where usable water supplies might be degraded.

Deep Well Injection

Injection into deep aquifers through wells might be acceptable if enough brine could be discharged without degrading local ground water. However, the brine might have to be treated prior to injection to prevent plugging of the aquifers by bacterial slimes or suspended materials.

Ocean Disposal

At coastal sites, the discharge of wastes into the ocean and connected bays has been common practice in the past. Today, however, regulations limiting both the temperature and concentration of salts in discharges of waste waters are becoming more restrictive.

APPENDIX C

BENEFITS ATTRIBUTABLE TO IMPROVED WATER QUALITY

APPENDIX C
BENEFITS ATTRIBUTABLE TO IMPROVED WATER QUALITY

Benefits may be used as a measure of the economic justification of a proposed desalting project. The justification is evaluated by relating the estimated benefits to be derived from desalting to the economic cost of the project.

For the project to be economically justifiable, the total economic benefits must exceed the total economic costs. However, even though the economic justification of a project may be established by such an evaluation, the ability to finance the project and repay the reimbursable costs are important factors in determining whether it will be constructed.

In an evaluation of the benefits of desalting, the benefits may be defined as the improvements that would result from the project, e.g., the increased service life of water heaters and plumbing fixtures, the reduced need for purchases of bottled water, and the decreased use of water softeners. The economic costs represent the cost of constructing and operating the necessary facilities, together with the tangible value of measures required to mitigate or prevent detrimental effects resulting from the desalting operation, such as (1) the cost of land required to dispose of large quantities of brine, (2) the cost of special measures required for protection of the environment, and (3) the tangible value of the remaining detrimental effects if mitigation is not complete.

The following table lists a number of chemical elements commonly found in community water supplies, along with the undesirable results of excessive concentrations of one or more of these chemicals:

Chemical Element	*Excessive Concentration results in:*
iron, manganese, bicarbonates	offensive color
iron, chlorides, TDS, manganese in combination with sulfate	offensive taste
hydrogen sulfide	offensive odor
iron, manganese	staining of plumbing fixtures, appliances, glassware, etc.
magnesium, calcium	hardness
chloride, sulfate	corrosion
fluoride, sodium, nitrate, arsenic, mercury	general detriment to public health
boron, chloride, TDS	detriment to lawns and plants

In a given community, a reduction (as by desalting) in the excessive concentration of one or more of the chemicals listed in the preceding table would create one or more benefits.

Types of Benefits

Benefits may be classified as primary or secondary, and tangible or intangible.

Primary benefits result from an increase in value of products or services, a reduction in costs, or a reduction in damage or losses. Examples of primary benefits are the increased service life of water-using appliances and plumbing fixtures, elimination of the need for water softeners and bottled water, and the reduced requirement for washing powders and soap.

Secondary benefits are indirect benefits that may be attributed to a project. An example of an indirect benefit is the improved appearance of a community, which may attract new residents and increase economic activity.

Both primary and secondary benefits may be tangible or intangible. Tangible benefits are those that can be calculated in dollars, such as the cost of bottled water. Intangible benefits, such as improved growing conditions for lawns and plants, cannot be readily expressed in monetary terms.

Primary Benefits

Primary benefits that could result from desalting will depend on the specific water quality problem in a given community. The benefits resulting from reductions of excessive mineral concentrations in community water supplies fall into three general categories:

- those resulting from reductions in TDS.
- those resulting from reductions in hardness.
- those resulting from reductions in specific ions.

The benefits that fall into each of these categories are as follows. [1]

1. *Benefits resulting from reduced TDS concentration*
   a. reduced purchases of bottled water. (T) [2]
   b. less frequent replacement of appliances. (T)
   c. less frequent maintenance and replacement

[1] Some benefits may fall into two or all three categories. Therefore, when a water quality problem involves more than one of these categories, a specific benefit should be counted only once.

[2] (T) = tangible benefit; (I) = intangible benefit or combination of tangible and intangible

of cooling, air conditioning, and heating equipment. (T)

d. reduced hazard to health. (I)

e. improved growing conditions for lawns and ornamental plants. (I)

2. *Benefits resulting from reduced hardness:*

a. elimination of need for mechanical water softners. (T)

b. reduced quantities of soaps, detergents, and other washing materials. (T)

c. less frequent replacement of appliances. (T)

d. less frequent replacement of water pipes and plumbing fixtures. (T)

e. less frequent maintenance and replacement of cooling, air conditioning, and heating equipment. (T)

f. increased usable life of clothing and linens, etc. (T)

g. enhanced appearance of freshly washed dishes and glassware. (I)

3. *Benefits resulting from reduced concentrations of specific ions:*

a. reduced buildup of corrosion. (I)

b. lower cost of building maintenance. (T)

c. reduced hazard to health. (I)

d. removal of offensive color, taste, and odor from water supplies. (I)

e. improved growing conditions for lawns and plants. (I)

Secondary Benefits

The creation of primary benefits is frequently accompanied by the creation of secondary benefits. A combination of primary and secondary benefits is exemplified by improved living conditions and an enhanced environment that will attract new industry or induce travelers to patronize local restaurants and motels. Secondary benefits are thus created through the additional goods and services provided to new residents and to travelers who patronize local commercial establishments.

Another important secondary benefit would result from the removal of a restriction, such as the prohibition of new water connections, imposed by a state or local regulatory agency. The removal of such a restriction might enable new construction, or the completion of a partially developed subdivision, etc., which would require additional goods and services and attract new residents.

Evaluation of Benefits

In this preliminary study of 10 California communities, dollar values of possible benefits were not determined. However, Chapter IV provides discussions of benefits and actual examples relevant to each community. This information was obtained through interviews with community representatives.

More detailed studies of each community will be required to develop accurate dollar estimates of tangible benefits that could result from desalting. The benefits could be established by determining the difference in costs of water service to community residents with and without desalting. The costs without desalting would be the sum of (1) the penalty costs to residents, (2) the cost of any special treatment required before the water supplies are used in the community, and (3) the costs of any special treatment required before waste water can be discharged from the community.

In such a case, the penalty cost results from the use of poor-quality water supplies, which, in turn, results in additional expenditures that may not be readily associated with water quality. Examples of penalty costs resulting from excessive hard water are the increased use of cleaning materials, rapid deterioration of plumbing fixtures and appliances, and reduced flows and water pressure caused by mineral deposits in water pipes.

The additional studies to evaluate benefits would require detailed local surveys to determine (1) the magnitude of the changes that would result from desalting in a given community, and (2) the development of a dollar measure of the unit value of each change. Additional information would also be required to evaluate the secondary benefits resulting from an improved economic climate and an enhanced community environment.

As explained in the preceding paragraphs, the primary benefits of desalting in a given community result from (1) reduced expenditures for certain commodities or services, e.g., bottled water, washing materials, and maintenance of appliances; (2) increased value of commodities or services, e.g., longer useful life of appliances; (3) reduced damage or losses, e.g., corroded pipelines and appliances, and (4) reduced hazards to public health. The following paragraphs discuss such benefits.

Bottled Water

When the mineral content of domestic water supplies is high, residents may complain of unpleasant tastes and odors and frequently will purchase bottled water, which has a low mineral content. Chlorides, fluorides, iron, and sulfates produce a noticeable

taste; organic material and chlorination may create both taste and odor problems.

The quantity of bottled water used in a given community varies greatly because of personal likes and dislikes. For example, long-time residents who have become accustomed to highly saline water may feel that bottled water tasts "flat" whereas new residents and travelers may dislike the "salty" taste of brackish community water supplies. Purchases of bottled water will also be affected by the climate in a given area and the marketing efforts of the purveyors.

Water-Using Appliances

Water-using appliances used with highly mineralized water generally require frequent service and replacement. The most serious problems are corrosion and accumulation of scale in such appliances as water heaters, dish washers, and clothes washing machines.

When water supplies are hard or contain excessive concentrations of TDS or chlorides, a water heater may last only a fraction of its normal guaranteed life. Heated water containing calcium and magnesium forms precipitates (scale), which results in lower heat-transfer capability, lower capacity, and increased fuel costs.

Hard water used in washing machines produces mineral deposits inside the machine, increases the cost of maintenance, and shortens the service life of the appliance. When mineral deposits have accumulated for some time, the cost of reconditioning may equal the cost of a new machine. Many homeowners have other water-using appliances, such as ice makers, water softeners, water coolers, and garbage grinders. High TDS concentrations and hardness in water supplies increase the frequency of replacement and the cost of maintaining such appliances.

Water Softening Equipment

Where water is excessively hard, some means of softening will usually be required. High concentrations of calcium and magnesium cause hardness in water, resulting in deposits of scale on metal surfaces and decreased effectiveness of washing materials. Scale and corrosion result in frequent maintenance and replacement of water pipes, plumbing fixtures, faucets, and valves. The formation of heavy scale may greatly reduce the effective inside diameter of pipes, thus reducing water pressure, In such cases, the pipes usually must be replaced. Deposits of scale will also cause infrequently used valves to "freeze" in position.

Two examples of savings that can be realized through the use of water softening equipment are provided by the results of studies of six motels in the Chicago area and an 1,100-bed hospital in Ottawa, Canada.

Water supplied to the motels ranged in hardness from 135 to 360 ppm. The studies showed that the additional cost of treatment to soften the water was repaid by savings in operating costs. The savings resulted from fewer hours worked by cleaning personnel, reduced purchases of cleaning materials, fewer plumbing repairs, and reduced maintenance of ice cube machines, air conditioners, and swimming pools. The largest savings were realized from a reduction in hourly wages paid for maid service.

Until softening equipment was installed in the Ottawa hospital, a 110,000-pound weekly wash had been laundered with hard water. After the water was softened, the cost of washing materials was reduced 50 percent, the cost of equipment maintenance was reduced, and the appearance of the wash was greatly improved.

Cleaning Materials

Excessively hard water requires the use of large quantities of detergents, soaps, softening agents, scouring compounds, and bleaches. These are generally used in all households and in such commercial establishments as restaurants, laundries, motels, hotels and hospitals. When water supplies are excessively hard, increased cleaning costs results from the higher costs of cleaning materials and the increased cost of labor.

Clothing and linens represent a large investment in most households; linens are also a large investment in hospitals, restaurants, motels and hotels. Where water is hard, dirt particles and dried soap curd become trapped in fabrics and generally shorten their useful lives.

The appearance of dishes, glassware, and silverware in restaurants has considerable unspoken sales appeal. Water marks, streaks, etc. may cause customers to stay away. When hard water is used in a dish washing machine, detergents can be used in the wash cycle but not in the rinse and sanitizing cycles. Unless the rinse water is softened, mineral deposits will cause streaks and spots on dishes, glassware, etc.

Polyphosphate detergents can be used to control hardness and cause soil particles to be suspended in water. With excessively hard water, large amounts of detergent must be used; a less expensive method of softening would be to reduce the concentration of hardness ions in the water.

The use of regenerative water softeners often results in a secondary problem. Where water is excessively hard, the softeners require frequent recharging, and the waste brines are usually discharged into the local waste water disposal system. Excessive salts in waste discharges may percolate into and impair the quality of usable ground water.

Excessive iron in water supplies will stain sinks,

plumbing fixtures, and appliances. Clothes washed in water containing excessive iron will gradually develop a yellow tint; in such cases, the use of bleaches increases the problem. Water containing excessive iron will also stain the exterior of buildings, sidewalks, etc., increasing the cost of maintenance and repainting.

Public Health

Domestic water supplies must meet certain minimum quality standards established by regulatory agencies, such as the U. S. Public Health Service and the California Department of Health. When the mineral content of water supplies in a given community would result in a hazard to public health, desalting to reduce excessive minerals would produce a benefit to that community.

Lawn Turf and Plants

Except during the rainy season, lawns, shrubs, and plants must be irrigated with local water supplies. Excessive boron or chlorides in water used for irrigation can retard the growth of plants and the development of grass cover, etc.

The success of such commercial enterprises as nurseries and golf courses is dependent on the healthful appearance of grass, plants, and shrubs, and the reduction of excessive mineral content in irrigation water would produce primary benefits for the owners of such concerns. The development of parks and similar civic improvements also enhance the general quality of community life.

APPENDIX D

QUALITY STANDARDS FOR DOMESTIC WATER SUPPLIES

APPENDIX D

QUALITY STANDARDS FOR DOMESTIC WATER SUPPLIES

The water quality standards included in this appendix are only those that apply to water quality conditions that can be influenced by the desalting of saline and brackish waters.

Part I, Chapter 5, Subchapter 1 of the California Administrative Code states:

> "Water containing substances exceeding the limits shown in Tables A and B presents a risk to the health of humans when used for drinking or culinary purposes.

Table A

Constituents	Limiting Concentration (mg/l)
Arsenic	0.10
Borium	1.0
Cadmium	0.01
Chromium	0.05
Cyanide	0.2
Lead	0.05
Mercury	0.005
Nitrate - N + Nitrite -N	10.0
Selenium	0.01

Table B
Limiting Fluoride Concentrations*

Annual Average of Maximum Daily Air Temperatures** (°F)	Fluoride Concentration (mg/l) Lower	Optimum	Upper
50 - 54	0.9	1.2	1.7
55 - 58	0.8	1.1	1.5
59 - 64	0.8	1.0	1.3
65 - 71	0.7	0.9	1.2
72 - 79	0.7	0.8	1.0
80 - 81	0.6	0.7	0.8

* The average concentration of fluoride during any month, if added, shall not exceed the upper limit, and if occurring naturally, shall not exceed twice the optimum. Based on 1962 PHS Drinking Water Standards.

**Based on temperature data obtained for a minimum of five years.

For consumer acceptance limits the Code states,

"Water containing substances exceeding limits listed in Tables C and D may be objectionable to an appreciable number of persons but are not hazardous to health.

Table C

Constituents	mg/l
Copper	1.0
Iron	0.3
Manganese	0.05
Zinc	5.0
Color - Units	15
Odor - Threshold	3

"(a) Constituent concentrations in the distribution system should not exceed the values in Table C. For iron and manganese, the value may be exceeded only if (1) adequate chemical treatment is provided which prevents development of visible precipitates or staining properties objectionable to consumers, or (2) in the judgment of the Department (Department of Health) the water is acceptable to the consumers.

"(b) For the chemical constituents shown on Table D, no fixed consumer acceptance limit has been established. In general, acceptance is reduced as mineralization increases.

Table D

Constituents	Recommended Limit (mg/l)	Upper Limit (mg/l)	Short-Term Limit (mg/l)
Total Dissolved Solids	500	1,000	1,500
Specific Conductance	800 micromhos	1,600 micromhos	2,400 micromhos
Chloride	250	500	600
Sulfate	250	500	600

"(1) Constituent concentrations lower than the Recommended Limit are desirable for a higher degree of consumer acceptance.

"(2) Constituent concentrations up to the Upper Limit are acceptable when it is not reasonable and feasible to provide more suitable waters.

"(3) Constituent concentrations up to the Short-Term Limit are acceptable only for existing systems and on a temporary basis pending construction of treatment facilities or development of acceptable new

water sources. New Services from systems serving water which carries constituent concentrations up to the Short-Term Limit will be allowed only if adequate progress is being demonstrated toward providing water of improved mineral quality."

APPENDIX E

CALCULATION OF RECOVERY

APPENDIX E
CALCULATION OF RECOVERY

Appendix E discusses methods used to estimate the maximum recovery of high-quality water as a result of desalting brackish or saline water supplies.

Definitions

One of the measures of efficiency of a desalting plant is the recovery, which is defined as follows:

$$\text{Recovery (R)} = \frac{\text{quantity of desalted water}}{\text{quantity of feed water}}$$

In evaluation studies for desalting plants, the value used for recovery has a dramatic effect on the size of evaporation ponds and a lesser but significant effect on the overall costs of desalting. A low recovery results in greater quantities of feed water and brine for a given quantity of desalted water, resulting in increased costs of evaporation ponds and pumping.

Another way of expressing this parameter is the brine-to-product ratio which is defined as follows:

$$\text{Brine-to-Product Ratio (BPR)} = \frac{\text{quantity of brine}}{\text{quantity of desalted water}}$$

The brine-to-product ratio can be obtained from the recovery by using the formula:

$$\text{BPR} = \frac{1}{R} - 1$$

Methods

The brine-to-product ratio was calculated in several different ways for the studies of the ten communities.

Vertical Tube Evaporation and Ion Exchange

When vertical tube evaporation or ion exchange methods were being considered, the formulas in the OSW Desalting Handbook for Planners were used.

Vapor Compression

Since formulas for the vapor compression method were not included in the OSW handbook, values obtained from the manufacturers were used exclusively.

Reverse Osmosis and Electrodialysis

Two methods of calculating the brine-to-product ratio were used when reverse osmosis and electrodialysis were being considered.

OSW Method. (from OSW Desalting Handbook for Planners)

$$BPR = \frac{1 - \frac{TDS_p}{TDS_i}}{\frac{900}{Ca_i} - 11}$$

where TDS_p = total dissolved solids of product
TDS_i = total dissolved solids of feedwater
Ca_i = calcium concentration of feedwater

In addition the handbook shows minimum values for BPR of 0.11 for reverse osmosis and 0.15 for electrodialysis.

UCLA Method. Detailed analyses of feedwater conditions for communities where reverse osmosis and electrodialysis were considered were sent to Professor J. W. McCutchan at the University of California. Professor McCutchan arranged for the calculation of concentration factors through use of a computer program developed at Oak Ridge National Laboratory by W. L. Marshall.

The program gives concentration factors based on the ionic strength of nine constituents and the temperature of the solution. The concentration factor is defined as follows:

$$\text{Concentration Factor (CF)} = \frac{\text{concentration of brine}}{\text{concentration of feedwater}}$$

The concentration factors are for the $CaSO_4 \cdot 2H_2O$ (gypsum) solubility limits, i.e., those values at which gypsum begins to precipitate.

Figure E-1 shows the printout from the computer. Figure E-2 shows the relevant data from the printout in graph form.

Table E-1 shows the concentration factor and maximum recovery, assuming a product concentration of zero and an operating temperature of 70° F.

$$\text{Maximum Recovery } (R_m) = 1 - \frac{1}{CF}$$

Table E-1. Maximum Recovery Values ($TDS_p = 0$)

Community	Concentration Factor	Maximum Recovery	Brine-to-Product Ratio
Boron	13.9	0.928	0.08
Buellton	7.9	0.874	0.14
Old Cuyama	0.88	0	∞
New Cuyama	3.1	0.678	0.47
Gaviota	4.5	0.778	0.29
Greenfield	6.8	0.853	0.17
Havasu	3.1	0.678	0.47
Refugio	2.4	0.583	0.72
Winterhaven	4.5	0.778	0.29
Operating Temperature: 70° F Product Concentration: 0			

Table E-2 shows the concentration factor and maximum recovery assuming a product concentration of 500 parts per million. In this case:

$$\text{Maximum Recovery } (R_m) = \frac{CF - 1}{CF - \frac{1}{D_r}}$$

$$\text{where } D_r = \text{Desalination Ratio} = \frac{\text{concentration of feed water}}{\text{concentration of product}}$$

BORON

SAMPLE NUMBER	IONIC STRENGTH	CALCIUM MOLALITY	SULFATE/CALCIUM	MAGNESIUM MOLALITY
1	0.2243E-01	0.1624E-02	0.1457E 01	0.6177E-03

CALCIUM=	65.	PPM	0.001624	MOLAL
MAGNESIUM=	15.	"	0.000618	"
SODIUM=	295.	"	0.012841	"
POTASSIUM=	7.	"	0.000179	"
BORON=	1.	"	0.000093	"
SULFATE=	227.	"	0.002366	"
BICARBONATE=	182.	"	0.002987	"
CHLORIDE=	338.	"	0.009545	"
NITRATE=	3.	"	0.000048	"

CONCN FACTORS FOR CASO4 DIHYDRATE).CF=CONCN(SATD)/CONCN(INITIAL)

TEMP(C)	CF(MOLAL)	CF(MOLAR)	CF(WT FRACT)	ION STR(MOLAL-SATD)	SOLY PD(ZERO)	NO ITER
0.	0.115E 02	0.115E 02	0.114E 02	0.258E 00	0.342E-04	9
10.	0.129E 02	0.128E 02	0.127E 02	0.289E 00	0.391E-04	9
25.	0.142E 02	0.141E 02	0.140E 02	0.319E 00	0.423E-04	9
40.	0.146E 02	0.145E 02	0.143E 02	0.327E 00	0.414E-04	9

BUELLTON

SAMPLE NUMBER	IONIC STRENGTH	CALCIUM MOLALITY	SULFATE/CALCIUM	MAGNESIUM MOLALITY
2	0.2203E-01	0.3097E-02	0.8917E 00	0.2512E-02

CALCIUM=	124.	PPM	0.003097	MOLAL
MAGNESIUM=	61.	"	0.002512	"
SODIUM=	57.	"	0.002481	"
POTASSIUM=	2.	"	0.000051	"
BORON=	0.	"	0.000000	"
SULFATE=	265.	"	0.002761	"
BICARBONATE=	399.	"	0.006547	"
CHLORIDE=	53.	"	0.001497	"
NITRATE=	0.	"	0.000000	"

CONCN FACTORS FOR CASO4 DIHYDRATE).CF=CONCN(SATD)/CONCN(INITIAL)

TEMP(C)	CF(MOLAL)	CF(MOLAR)	CF(WT FRACT)	ION STR(MOLAL-SATD)	SOLY PD(ZERO)	NO ITER
0.	0.632E 01	0.631E 01	0.628E 01	0.139E 00	0.342E-04	9
10.	0.718E 01	0.716E 01	0.713E 01	0.158E 00	0.391E-04	9
25.	0.807E 01	0.805E 01	0.800E 01	0.178E 00	0.423E-04	9
40.	0.844E 01	0.841E 01	0.836E 01	0.186E 00	0.414E-04	10

OLD CUYAMA

SAMPLE NUMBER	IONIC STRENGTH	CALCIUM MOLALITY	SULFATE/CALCIUM	MAGNESIUM MOLALITY
3	0.1226E 00	0.1604E-01	0.1728E 01	0.1033E-01

CALCIUM=	640.	PPM	0.016042	MOLAL
MAGNESIUM=	250.	"	0.010332	"
SODIUM=	320.	"	0.013978	"
POTASSIUM=	10.	"	0.000257	"
BORON=	0.	"	0.000000	"
SULFATE=	2650.	"	0.027715	"
BICARBONATE=	309.	"	0.005089	"
CHLORIDE=	195.	"	0.005526	"
NITRATE=	243.	"	0.003938	"

CONCN FACTORS FOR CASO4 DIHYDRATE).CF=CONCN(SATD)/CONCN(INITIAL)

TEMP(C)	CF(MOLAL)	CF(MOLAR)	CF(WT FRACT)	ION STR(MOLAL-SATD)	SOLY PD(ZERO)	NO ITER
0.	0.729E 00	0.729E 00	0.730E 00	0.893E-01	0.342E-04	7
10.	0.816E 00	0.816E 00	0.817E 00	0.100E 00	0.391E-04	7
25.	0.897E 00	0.897E 00	0.898E 00	0.110E 00	0.423E-04	7
40.	0.917E 00	0.917E 00	0.917E 00	0.112E 00	0.414E-04	7

Figure E-1. Computer Calculation of Concentration Factors

NEW CUYAMA

SAMPLE NUMBER	IONIC STRENGTH	CALCIUM MOLALITY	SULFATE/CALCIUM	MAGNESIUM MOLALITY
4	0.3733E-01	0.3698E-02	0.2630E 01	0.2884E-02

		PPM		MOLAL
CALCIUM=	148.	PPM	0.003698	MOLAL
MAGNESIUM=	70.	"	0.002884	"
SODIUM=	123.	"	0.005356	"
POTASSIUM=	5.	"	0.000128	"
BORON=	0.	"	0.000000	"
SULFATE=	933.	"	0.009727	"
BICARBONATE=	175.	"	0.002873	"
CHLORIDE=	30.	"	0.000848	"
NITRATE=	14.	"	0.000226	"

CONCN FACTORS FOR CASO4 DIHYDRATE),CF=CONCN(SATD)/CONCN(INITIAL)

TEMP(C)	CF(MOLAL)	CF(MOLAR)	CF(WT FRACT)	ION STR(MOLAL-SATD)	SOLY PD(ZERO)	NO ITER
0.	0.262E 01	0.262E 01	0.261E 01	0.978E-01	0.342E-04	8
10.	0.293E 01	0.293E 01	0.292E 01	0.109E 00	0.391E-04	8
25.	0.321E 01	0.321E 01	0.320E 01	0.120E 00	0.423E-04	8
40.	0.327E 01	0.327E 01	0.326E 01	0.122E 00	0.414E-04	8

GAVIOTA

SAMPLE NUMBER	IONIC STRENGTH	CALCIUM MOLALITY	SULFATE/CALCIUM	MAGNESIUM MOLALITY
5	0.4684E-01	0.5451E-02	0.9187E 00	0.2103E-02

		PPM		MOLAL
CALCIUM=	218.	PPM	0.005451	MOLAL
MAGNESIUM=	51.	"	0.002103	"
SODIUM=	320.	"	0.013944	"
POTASSIUM=	5.	"	0.000128	"
BORON=	3.	"	0.000278	"
SULFATE=	480.	"	0.005008	"
BICARBONATE=	360.	"	0.005915	"
CHLORIDE=	700.	"	0.019790	"
NITRATE=	71.	"	0.001148	"

CONCN FACTORS FOR CASO4 DIHYDRATE),CF=CONCN(SATD)/CONCN(INITIAL)

TEMP(C)	CF(MOLAL)	CF(MOLAR)	CF(WT FRACT)	ION STR(MOLAL-SATD)	SOLY PD(ZERO)	NO ITER
0.	0.375E 01	0.374E 01	0.372E 01	0.175E 00	0.342E-04	8
10.	0.422E 01	0.421E 01	0.418E 01	0.198E 00	0.391E-04	9
25.	0.468E 01	0.466E 01	0.463E 01	0.219E 00	0.423E-04	9
40.	0.481E 01	0.479E 01	0.476E 01	0.225E 00	0.414E-04	9

GREENFIELD

SAMPLE NUMBER	IONIC STRENGTH	CALCIUM MOLALITY	SULFATE/CALCIUM	MAGNESIUM MOLALITY
6	0.1554E-01	0.2896E-02	0.8417E 00	0.0000E 00

		PPM		MOLAL
CALCIUM=	116.	PPM	0.002896	MOLAL
MAGNESIUM=	0.	"	0.000000	"
SODIUM=	59.	"	0.002567	"
POTASSIUM=	5.	"	0.000128	"
BORON=	0.	"	0.000000	"
SULFATE=	234.	"	0.002438	"
BICARBONATE=	278.	"	0.004561	"
CHLORIDE=	85.	"	0.002400	"
NITRATE=	5.	"	0.000081	"

CONCN FACTORS FOR CASO4 DIHYDRATE),CF=CONCN(SATD)/CONCN(INITIAL)

TEMP(C)	CF(MOLAL)	CF(MOLAR)	CF(WT FRACT)	ION STR(MOLAL-SATD)	SOLY PD(ZERO)	NO ITER
0.	0.562E 01	0.561E 01	0.560E 01	0.873E-01	0.342E-04	8
10.	0.626E 01	0.625E 01	0.623E 01	0.972E-01	0.391E-04	8
25.	0.683E 01	0.682E 01	0.679E 01	0.106E 00	0.423E-04	8
40.	0.692E 01	0.691E 01	0.689E 01	0.108E 00	0.414E-04	8

HAVASU

SAMPLE NUMBER	IONIC STRENGTH	CALCIUM MOLALITY	SULFATE/CALCIUM	MAGNESIUM MOLALITY
7	0.3850E-01	0.4548E-02	0.1818E 01	0.1112E-02

CALCIUM=	182.	PPM	0.004548	MOLAL
MAGNESIUM=	27.	"	0.001112	"
SODIUM=	304.	"	0.013239	"
POTASSIUM=	8.	"	0.000205	"
BORON=	0.	"	0.000000	"
SULFATE=	793.	"	0.008269	"
BICARBONATE=	141.	"	0.002315	"
CHLORIDE=	194.	"	0.005482	"
NITRATE=	3.	"	0.000048	"

CONCN FACTORS FOR CASO4 DIHYDRATE),CF=CONCN(SATD)/CONCN(INITIAL)

TEMP(C)	CF(MOLAL)	CF(MOLAR)	CF(WT FRACT)	ION STR(MOLAL-SATD)	SOLY PD(ZERO)	NO ITER
0.	0.255E 01	0.255E 01	0.254E 01	0.982E-01	0.342E-04	7
10.	0.285E 01	0.285E 01	0.284E 01	0.110E 00	0.391E-04	8
25.	0.312E 01	0.312E 01	0.311E 01	0.120E 00	0.423E-04	8
40.	0.318E 01	0.317E 01	0.316E 01	0.122E 00	0.414E-04	8

REFUGIO

SAMPLE NUMBER	IONIC STRENGTH	CALCIUM MOLALITY	SULFATE/CALCIUM	MAGNESIUM MOLALITY
9	0.6185E-01	0.9030E-02	0.9709E 00	0.5691E-02

CALCIUM=	361.	PPM	0.009030	MOLAL
MAGNESIUM=	138.	"	0.005691	"
SODIUM=	239.	"	0.010418	"
POTASSIUM=	6.	"	0.000154	"
BORON=	0.	"	0.000000	"
SULFATE=	840.	"	0.008767	"
BICARBONATE=	635.	"	0.010436	"
CHLORIDE=	307.	"	0.008682	"
NITRATE=	4.	"	0.000065	"

CONCN FACTORS FOR CASO4 DIHYDRATE),CF=CONCN(SATD)/CONCN(INITIAL)

TEMP(C)	CF(MOLAL)	CF(MOLAR)	CF(WT FRACT)	ION STR(MOLAL-SATD)	SOLY PD(ZERO)	NO ITER
0.	0.194E 01	0.194E 01	0.194E 01	0.120E 00	0.342E-04	8
10.	0.220E 01	0.219E 01	0.219E 01	0.136E 00	0.391E-04	8
25.	0.245E 01	0.244E 01	0.244E 01	0.151E 00	0.423E-04	8
40.	0.254E 01	0.253E 01	0.252E 01	0.157E 00	0.414E-04	9

WINTERHAVEN

SAMPLE NUMBER	IONIC STRENGTH	CALCIUM MOLALITY	SULFATE/CALCIUM	MAGNESIUM MOLALITY
10	0.3143E-01	0.3698E-02	0.1449E 01	0.1895E-02

CALCIUM=	148.	PPM	0.003698	MOLAL
MAGNESIUM=	46.	"	0.001895	"
SODIUM=	208.	"	0.009056	"
POTASSIUM=	4.	"	0.000102	"
BORON=	0.	"	0.000000	"
SULFATE=	514.	"	0.005358	"
BICARBONATE=	290.	"	0.004761	"
CHLORIDE=	182.	"	0.005141	"
NITRATE=	0.	"	0.000000	"

CONCN FACTORS FOR CASO4 DIHYDRATE),CF=CONCN(SATD)/CONCN(INITIAL)

TEMP(C)	CF(MOLAL)	CF(MOLAR)	CF(WT FRACT)	ION STR(MOLAL-SATD)	SOLY PD(ZERO)	NO ITER
0.	0.382E 01	0.381E 01	0.380E 01	0.120E 00	0.342E-04	8
10.	0.429E 01	0.428E 01	0.426E 01	0.135E 00	0.391E-04	8
25.	0.474E 01	0.473E 01	0.471E 01	0.149E 00	0.423E-04	9
40.	0.486E 01	0.485E 01	0.482E 01	0.153E 00	0.414E-04	9

Figure E-1 (continued)

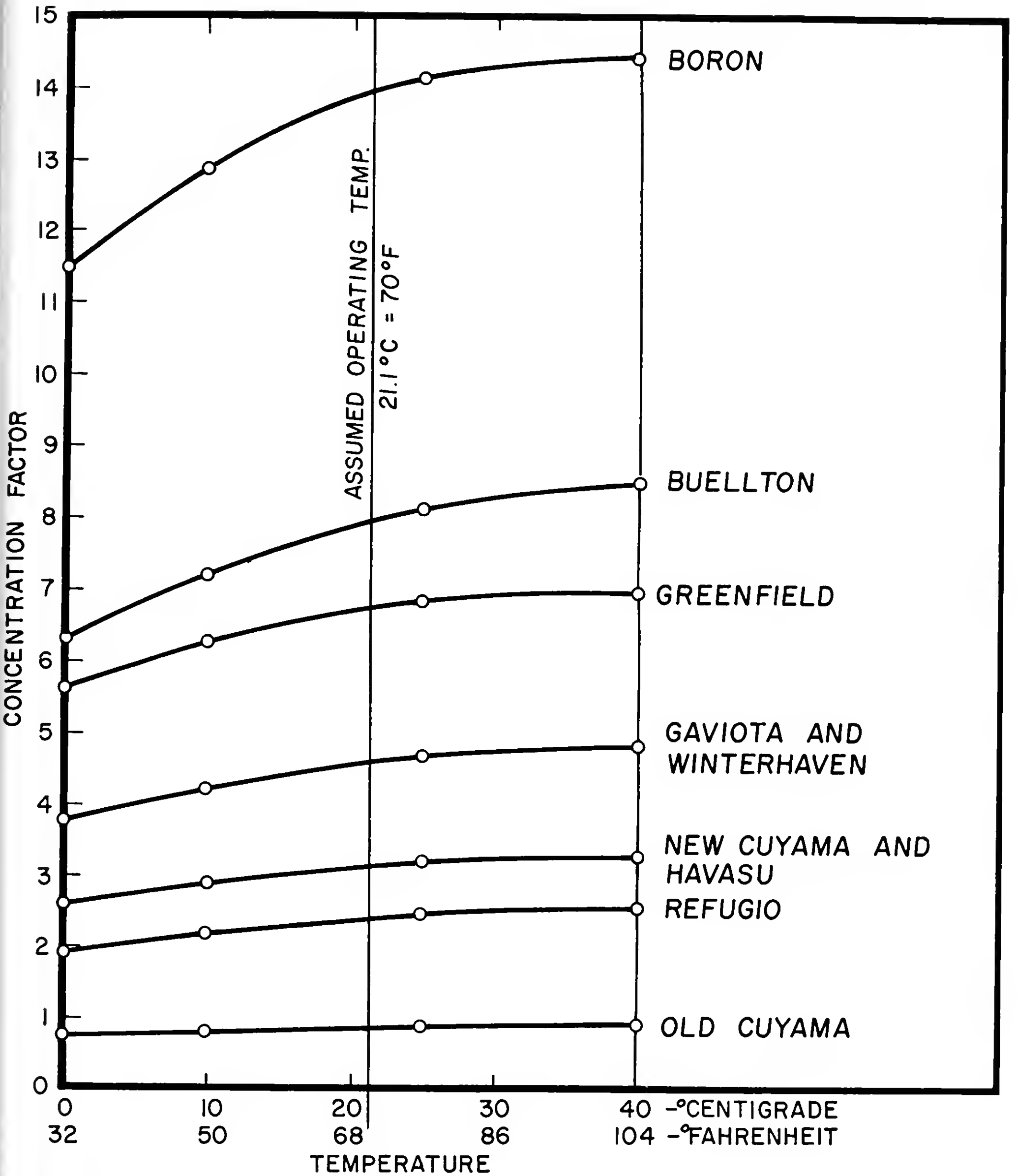


Figure E-2. Concentration Factors

Table E-2. Maximum Recovery Values (TDS_p = 500 ppm)

Community	TDS of Feed Water (ppm)	Desalination Ratio	Concentration Factor	Maximum Recovery	Brine-to-Product Ratio
Boron	1,034	2.07	13.9	0.961	0.04
Buellton	791	1.58	7.9	0.949	0.05
Old Cuyama	4,333	8.67	0.88	0	∞
New Cuyama	1,469	2.94	3.1	0.761	0.31
Gaviota	2,650	5.30	4.5	0.811	0.23
Greenfield	718	1.44	6.8	0.950	0.05
Havasu	1,702	3.40	3.1	0.748	0.34
Refugio	1,915	3.83	2.4	0.654	0.53
Winterhaven	1,370	2.74	4.5	0.846	0.18
Operating Temperature: 70° F Product Concentration: 500 ppm TDS					

In both tables, the maximum recovery at Old Cuyama is shown as zero. This is because, according to the computer program, gypsum was already beginning to precipitate in the feed water.

Comparison of Values. Table E-3 shows a comparison of brine-to-product ratios for five of the nine communities listed in the previous tables. Two of the communities omitted are New Cuyama, where revised data was received after the computed program had been run, and Old Cuyama, where the computer program produced a maximum recovery of zero. The other two communities omitted are Boron and Buellton, where BPR values were clearly significantly lower than the maximum allowable in the OSW handbook.

Table E-3. Comparison of Brine-to-Product Ratios

Community	TDS 1/ of Blended Product	Brine-to-Product Ratio				TDS 2/ of Blended Product	Brine-to-Product Ratio			
		Reverse Osmosis		Electrodialysis			Reverse Osmosis		Electrodialysis	
		OSW Method	UCLA Method	OSW Method	UCLA Method		OSW Method	UCLA Method	OSW Method	UCLA Method
Greenfield	500	0.11	<u>0.14</u>	<u>0.15</u>	0.14	147	0.12	<u>0.14</u>	<u>0.15</u>	0.14
Havasu	800	0.22	<u>0.405</u>	0.15	<u>0.36</u>	302	0.22	<u>0.39</u>	0.21	<u>0.39</u>
Winterhaven	500	0.13	<u>0.26</u>	0.15	<u>0.18</u>	245	0.16	<u>0.26</u>	0.16	<u>0.24</u>
Refugio	500	0.58	<u>0.625</u>	0.50	<u>0.53</u>	195	0.60	<u>0.65</u>	0.60	<u>0.65</u>
Gaviota	500	<u>0.29</u>	0.26	<u>0.26</u>	0.23	262	<u>0.29</u>	0.23	<u>0.29</u>	0.23

Note: Underlined numbers are the more conservative values used in the cost calculations.

1/ TDS required to meet communities requirements for TDS.

2/ TDS required to meet communities requirements for hardness.

86082 950 1-75 1M OSP